Performance evaluation in shipboard test of the DESMI Ocean Guard ballast water management system DOG P40-300

DESMI Ocean Guard A/S

Report

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Performance evaluation in shipboard test of the DESMI Ocean Guard ballast water management system DOG P40-300

Prepared for	**DESMI Ocean Guard A/S**
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Thurø Mærsk *in Port of Lisbon*

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Abbreviations

Abbreviation	Description
AVG	Average
BWMS	Ballast water management system
CFU	Colony-forming units
DOC	Dissolved organic carbon
DPM	Disintegrations per minute
FR	Field replicate
IMO	International Maritime Organization
MEPC	Marine Environment Protection Committee
MPN	Most probable number
NTU	Nephelometric turbidity units
POC	Particulate organic carbon
PSU	Practical salinity units
QAPP	Quality assurance project plan
QMP	Quality management plan
SOP	Standard operating procedure
STD	Standard deviation
TEU	Twenty foot equivalent unit
TSS	Total suspended solids
UVT	UV transmittance

1 Executive summary

DHI provides independent verification testing services to developers of ballast water management systems. DHI's quality assurance project plan is consistent with the requirements of the International Convention for the Control and Management of Ships Ballast Water and Sediments.

From September 2011 through April 2012, DHI conducted shipboard test of the DESMI Ocean Guard ballast water management system DOG P40-300 in accordance with DHI's certification by Lloyd's Register. The ability of the DOG P40-300 to (a) successfully treat ballast water without interruption and (b) meet IMO D-2 ballast water discharge standard was evaluated during a series of three valid test cycles.

The first two test cycles were conducted with ballast operations in the port of Lisbon, Portugal, and de-ballast operations in the port of Lisbon and in the port of Algeciras Bay, Spain, respectively. The third test cycle was conducted with ballast operation in the port of Praia, Republic of Cape Verde and de-ballast operation on anchorage site outside the port of Praia. The source water was characterized as marine water with salinities of approx. 34 and 37 practical salinity units (PSU), respectively, in the port of Lisbon and the port of Praia.

The average densities of viable organisms in the ≥50 µm size class varied from approx. 4,900 to approx. 10,000 organisms per m^3 in the inlet water. For the size class ≥10 and <50 µm, the average densities in inlet water varied from 94 to 127 organisms/mL when determined by inverted microscopy. The contents of *E. coli* and enterococci bacteria in the inlet water were <10-130 and <10-120, respectively. The inlet water concentrations of organisms ≥50 µm and the smaller planktonic organisms (≥10 and <50 µm) fulfilled the validity criteria defined in the IMO G8 guidelines. For shipboard testing, there are no requirements in the IMO G8 guidelines in relation to the density of bacteria in the inlet water.

The numbers of viable organisms in the ≥50 µm size class were 0.17, 0.26 and 0 per m^3 in the treated discharge water in the three test cycles, which is at least 40 times below the threshold value defined in the IMO D-2 standard. In all three test cycles, the density of viable algae, representing the ≥10 and <50 µm size class, in the treated discharge water was determined to <0.18 organisms/mL by use of a most probable number (MPN) assay. The density of viable algae in the treated discharge water was thus more than 55 times below the IMO D-2 standard. Measurements of the algal primary production showed a decrease of 99-100% after treatment in the ballast water management system compared with the control with untreated ballast water, which confirmed that the treatment resulted in an immediate impact on the algal photosynthesis. In the treated discharge water, the average concentrations of *E. coli* and enterococci were below the detection limit in all test cycles. *Vibrio cholerae* was not detected in any water sample in the shipboard test.

The DOG P40-300 functioned properly during all three test cycles and was highly effective at reducing live organism densities, fulfilling the IMO consistent challenge conditions. Live organisms in the size classes defined in the IMO G8 guidelines were discharged at densities below the IMO D-2 standard.

2 Introduction

The objective of this project was to conduct a shipboard test of the DESMI Ocean Guard ballast water management system (BWMS) DOG P40-300 in accordance with the guidance given in Resolution MEPC.174(58), Guidelines for approval of ballast water management systems (G8) (IMO 2008), hereafter referred to as the IMO G8 guidelines.

DHI holds a certificate of compliance issued by Lloyd's Register. The acting classification society for the shipboard test of the DOG P40-300 was Lloyd's Register.

DHI has no involvement, intellectual or financial, in the mechanics, design or marketing of the BWMS whose performance has presently been evaluated. To ensure that DHI tests are uncompromised by any real or perceived individual or team bias relative to test outcomes, DHI test activities are subject to rigorous quality assurance, quality control procedures and documentation.

During three consecutive valid test cycles, the DOG P40-300 was evaluated for its ability to: (a) successfully treat ballast water without interruption and (b) meet IMO D-2 standard (IMO 2004) at discharge.

3 Testing laboratory

DHI is an independent, international consulting and research organisation with the objectives to advance technological development and competence within the fields of water, environment and health. DHI established the DHI Ballast Water Centre with the purpose to provide performance evaluation of BWMS. The DHI Ballast Water Centre includes land-based test facilities and environmental laboratories in Denmark and Singapore.

The shipboard test was carried out by:

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4 Ballast water management system

A description of the DOG P40-300 as provided by DESMI Ocean Guard is included in the quality assurance project plan (QAPP) in Appendix B.

5 Experimental design

5.1 Trial periods and locations

The shipboard test included three consecutive valid test cycles conducted on board the container vessel Thurø Mærsk (IMO 8819976).

Thurø Mærsk is a cargo ship from 1991 with a cargo capacity of 1367 TEU (twenty foot equivalent unit). The vessel typically calls ports in Algeciras – Vigo – Leixoes and Lisbon on the Iberian Peninsula, a number of ports on the West African coast and in Praia in the Republic of Cape Verde.

In the beginning of September 2011, the DOG P40-300 was installed in a container placed in the bottom of the cargo bay and connected to the ballast water system of the vessel. For the shipboard testing, the starboard ballast tank 7 was used for control water and the port side ballast tank 7 was used for treated water.

Table 5.1 Details of inlet and discharge operations for shipboard test cycles

Test cycle	Location (ballast/ de-ballast)	Operation	Inlet	Volume and flow rate	Discharge	Volume and flow rate
Test#1	Lisbon (PT) / Lisbon (PT)	Control	2011.09.12 20:23-21:15	~ 260 m³ ~300 m³/h	2011.09.13 19:09-19:52	~140 m³ ~200 m³/h
		Treatment	2011.09.12 21:30-22:20	~210 m³ ~250 m³/h	2011.09.13 16:22-16:59	~120 m³ ~200 m³/h
Test#2	Lisbon (PT)/ Algeciras (ES)	Control	2011.09.14 06:09-06:59	~ 260 m³ ~310 m³/h	2011.09.16 16:01-16:31	~100 m³ ~200 m³/h
		Treatment	2011.09.14 08:09-09:12	~260 m³ ~250 m³/h	2011.09.16 14:28-15:00	~110 m³ ~200 m³/h
Test#3	Praia (CV) / Praia (CV)	Control	2012.04.23 14:09-15:08	~260 m³ ~264 m³/h	2012.04.24 10:47-11:20	~110 m³ ~200 m³/h
		Treatment	2012.04.23 15:30-16:22	~260 m³ ~300 m³/h	2012.04.24 09:25-10:03	~130 m³ ~200 m³/h

Ballast operations for test cycles #1 and #2 were conducted while docked at the Alcântara Container Terminal in the port of Lisbon, Portugal (PT). The de-ballast operations were conducted in the port of Lisbon for test cycle #1 and at the APM Terminal in the port of Algeciras Bay, Spain (ES), for test cycle #2. Test cycle #3 was conducted with ballast operation in the port of Praia, Republic of Cape Verde (CV) whereas the de-ballast operation was conducted on anchorage outside the port of Praia. The holding time of ballast water between inlet and discharge varied from 17 to 56 hours.

The BWMS was operated by DESMI Ocean Guard A/S and the vessel's crew during the three test cycles. Each test cycle consisted of sampling and analyses of:

- **Inlet water:** Physical-chemical and biological parameters in the inlet water were considered sufficiently stable during the ballasting and, thus, only one set of samples and analyses was used to represent the control tank and the ballast tank
- **Control discharge water:** Stored without treatment from the time of ballasting to discharge
- **Treated discharge water:** Treated and stored from the time of ballasting to discharge

5.2 Sampling

5.2.1 Sample overview

All samples were collected by DHI staff in accordance with the description in the QAPP (Appendix B).

Table 5.2 Number of samples and sample volumes

Water type	Sample replicates	Sample volume per replicate
Inlet water	3 replicates	Organisms ≥50 µm: >1 m^3 *
		Organisms ≥10 and 50 µm: >1 L **
		Bacteria: >0.5 L **
		DOC + POC: Approx. 0.5 L **
		TSS: Approx. 2 L **
Control discharge water	3 replicates	Organisms ≥50 µm: >1 m^3 *
		Organisms ≥10 and 50 µm: >1 L **
		Bacteria: >0.5 L **
		DOC + POC: Approx. 0.5 L **
		TSS: Approx. 2 L **
Treated discharge water	3 replicates	Organisms ≥50 µm: >3 m^3 *
	3 × 3 replicates	Organisms ≥10 and 50 µm: >1 L **
	3 × 3 replicates	Bacteria: >0.5 L **
	3 replicates	DOC + POC: Approx. 0.5 L **
	3 replicates	TSS: Approx. 2 L **

* Samples collected by continuous flow during the entire period of intake or discharge; this continuous sampling of 3 replicates, each with a volume of at >3 m^3, provides the same statistical basis for counting as the sampling 3 × 3 replicates of >1 m^3, which is recommended in the G8 guidelines;
** Samples collected over the period of intake or discharge (start, middle and end).
DOC Dissolved organic carbon
POC Particulate organic carbon
TSS Total suspended solids

5.2.2 Samples for enumeration of organisms ≥50 µm

Three replicates were collected by parallel continuous sampling during the entire periods of inlet and discharge. The samples were gently filtered through a net with a mesh size of 35 µm and a reservoir (cod-end) at the bottom for collecting the organisms ≥50 µm. Each replicate was transferred to 1-L glass bottles. The total volume of the filtered sample exceeded 3 m^3 per replicate for the treated discharge samples and 1 m^3 per replicate for the inlet and control discharge samples. The exact sample volume for each of the three replicates was determined by use of three flow meters, which were an integrated part of the sampling system for the DOG P40-300 unit.

5.2.3 Samples for enumeration of organisms ≥10 µm and <50 µm

Samples (3 replicates for the inlet water, 3 replicates for the control discharge water, and 3 × 3 replicates for the treated discharge water) with a volume of approx.. 10 L were collected in polyethylene containers.

5.2.4 Samples for enumeration of bacteria

Samples (3 replicates for the inlet water, 3 replicates for the control discharge water, and 3 × 3 replicates for the treated discharge water) with a volume of at least 0.5 L were collected in sterile polyethylene containers.

5.2.5 Samples for DOC, POC and TSS analyses

Samples (3 replicates for each water type) were collected in heat-sterilized blue cap bottles of at least 0.5 L for analysis of dissolved organic carbon (DOC) and particulate organic carbon (POC). For analysis of total suspended solids (TSS), appropriate sample volumes were taken from the samples described in Section 5.2.3.

5.3 Analyses

5.3.1 Analysis overview

Table 5.3 Overview of analyses and sample replicates

Replicate	Temperature	Salinity	≥ 50 µm	10-50 µm, primary production	10-50 µm, MPN	10-50 µm, Lugol's solution	Bacteria	DOC + POC	TSS
Inlet water									
Replicate 1 (start)	1	1	Three replicates	1	1	1	1	1	1
Replicate 2 (mid)	2	2		2	2	2	2	2	2
Replicate 3 (end)	3	3		3	3	3	3	3	3
Control discharge water									
Replicate 1 (start)	1	1	Three replicates	1	1	-	1	1	1
Replicate 2 (mid)	2	2		2	2	-	2	2	2
Replicate 3 (end)	3	3		3	3	-	3	3	3
Treated discharge water									
Replicate 1-3 (start)	1	1	Three replicates	1	1-3	-	1-3	1	1
Replicate 4-6 (mid)	4	4		4	4-6	-	4-6	4	4
Replicate 7-9 (end)	7	7		7	7-9	-	7-9	7	7

MPN Most probable number
DOC Dissolved organic carbon
POC Particulate organic carbon
TSS Total suspended solids

All analyses were carried out in accordance with the QAPP (Appendix B) and the relevant standard operating procedures (SOPs). The analyses were generally initiated within 4 h from the time of the collection of the samples with the exception of samples for the enumeration of bacteria in the control discharge water and the treated discharge water of test cycle #2, which were shipped to Denmark and analysed at the DHI laboratory.

Table 5.4 Sample storage temperature from sampling to analysis

Sample	Storage temperature (°C)			
	From sampling to handling on board (<4 h)	Storage on board (up to 100 h)	Transfer to airport (up to 24 h)	Shipment to DHI (up to 96 h)
Organisms ≥50 µm	10-18	-	-	-
Organisms ≥10 and <50 µm (primary production)	10-18	-	-	-
Organisms ≥10 and <50 µm (MPN)	10-18	22-27	22-29	19-29
Organisms ≥10 and <50 µm (Lugol's solution)	10-18	1-4	10-20	10-24
Bacteria, DOC, POC, TSS	10-18	1-4	10-20	10-24

MPN Most probable number
DOC Dissolved organic carbon
POC Particulate organic carbon
TSS Total suspended solids

5.3.2 Organism size class ≥50 µm

In the samples, the concentrations of viable organisms ≥50 µm in the samples were determined by using a stereo microscope and a counting chamber. Viable organisms were determined after staining with Neutral Red on the basis of observed mobility and morphology according to DHI SOP 30/1700. The viable organisms were characterized according to broad taxonomic groups. The samples were maintained at 10-18°C in darkness until initiation of the analyses. The analyses were completed within 4 hours from the time of collection of the samples. Compliance with the IMO D-2 standard (IMO 2004) was verified by using the direct count of viable organisms ≥50 µm.

5.3.3 Organism size class ≥10 µm and <50 µm

The polyethylene container with an approximate sample volume of 10 L was gently turned upside down five times, after which subsamples were taken for the analyses described below.

Organisms in inlet water

One subsample per replicate, with a volume of approx. 10 mL, was transferred to 10-mL polyethylene tubes with screw-caps. The concentrations of viable algae were determined by use of a most probable number (MPN) assay. A dilution series was made for each replicate and 1-mL aliquots containing 1 mL, 0.1 mL and 0.01 mL of the subsample were added to series of five test tubes with 5 mL of liquid medium. Blank controls containing 5 mL of liquid medium without sample were also prepared. The test tubes were sealed and kept in the dark at a temperature between 19 and 29°C on board the vessel and during transport to the DHI laboratory. Upon arrival at the laboratory, the fluorescence of the test tubes was determined prior to incubation. The concentrations of viable algae in the samples were determined by measuring the fluorescence in the test tubes after 14 days of incubation under continuous light. Incubation temperatures were 20°C for the MPN assays in test cycles #1 and #2 and 22°C for the MPN assay in test cycle #3.

The concentrations of organisms in the size class ≥10 and <50 µm were determined in the DHI laboratory by inverted microscopy. On location, two subsamples per replicate, each of a volume of approx. 100 mL, were transferred from the inlet water samples to brown 100-mL glass bottles. The subsamples were preserved by addition of Lugol's solution to achieve 2% final concentration. The identification comprised detailed examination of the algal chloroplasts to confirm that the organisms had been alive when sampled and classification of the algae in major taxonomic groups.

The algal primary production was determined by measuring the ^{14}C fixed by photosynthesis. Two subsamples per replicate, each of a volume of approx. 60 mL, were transferred to 60-mL bottles and $NaH^{14}CO_3$ (2 µCi) was added to each bottle. The bottles were incubated for approx. 75 min under light from a light-panel. The incubation took place in a container at 22-26°C, and the bottles were gently rotated every 15 min to ensure mixing of the algae. After incubation, the samples were filtered onto Whatman GF/D filters, and the filters were transferred to glass vials, after which 200 µL 0.1 N HCl was added directly to the filters. The ^{14}C activity remaining in the algae on the filters after acidification was quantified by liquid scintillation counting.

Organisms in discharge water

The concentrations of viable algae in the control discharge water and the treated discharge water were determined by use of the MPN assay (the possible presence of heterotrophic microzooplankton was examined by use of the method in DHI SOP 30/1701). Compliance with the IMO D-2 standard (IMO 2004) was verified by use of the results of the MPN assay. As a supporting parameter, measurements of primary production were conducted by use of the method described above.

5.3.4 Bacteria

The concentrations of *E. coli* and enterococci were determined by diluting the samples in sterilized water (1:1), after which the samples were distributed in a specific 96-wells test kit for either *E. coli* or enterococci (BIO-RAD, MUG/MUD kits for *E. coli* or enterococci quantification). The inoculated test kits were incubated for 36 hours at 44°C (42°C to 44.5°C), after which positive wells were used to calculate the most probable numbers.

Samples for detection of *Vibrio cholerae* were filtered through a 0.45-µm filter, after which the filters were placed in a sterile container. The containers with the filters were kept in the dark at 1-4°C on board the vessel whereas the temperature during transport from the on-board location (Algeciras, 2011.09.17) to the DHI laboratory (arrival, 2011.09.20) was 10-24°C. Upon arrival at the DHI laboratory, the filters were submerged into alkaline saline peptone water for two selective enrichments. In test cycle #3, the filters were submerged in alkaline saline peptone on-board the vessel and kept at temperatures of 22-27°C until arrival in the DHI laboratory. The cultures obtained by the enrichments were used for inoculation of agar plates. Following 24 hours of incubation at 37 ± 1°C, the morphology of the colonies on the agar plates was inspected. Three of the inspected colonies were sent to DTU Food (mailing address: DTU Food, Zoonoselab, Mørkhøj Bygade, Bygning H, DK-2860, Søborg, Denmark) for verification of *Vibrio cholerae*.

5.3.5 Physical-chemical parameters

Dissolved oxygen, salinity, temperature and pH were measured by use of a portable multi parameter instrument equipped with electrodes. Measurements were conducted at regular intervals throughout the inlet and discharge operations.

Samples for determination of organic carbon content were filtered through a 0.45-µm syringe filter. By using a TOC analyser, the TOC was determined by analysis of non-filtered sample whereas the DOC was determined by analysis of filtered sample. The POC was calculated as the difference between TOC and DOC.

Samples for determination of TSS were filtered through a glass fibre filter, which had already been weighed in the laboratory, and the TSS was determined by weighing of filters containing sample after drying at 105°C.

6 Results

6.1 Physical-chemical parameters

The physical-chemical conditions of inlet and discharge waters are summarized in Table 6.1. Detailed data for TSS, POC and DOC are available in Appendix A.

Table 6.1 Average concentrations of total suspended solids (TSS), particulate organic carbon (POC) and dissolved organic carbon (DOC).

Test cycle	Water type	TSS (mg/L)	POC (mg/L)	DOC (mg/L)
Test#1	Inlet water	59	1.3	0.68
	Control discharge water	15	0.77	0.62
	Treated discharge water	14	0.55	0.73
Test#2	Inlet water	48	1.2	0.64
	Control discharge water	4.0	0.62	0.51
	Treated discharge water	3.7	0.45	0.63
Test#3	Inlet water	11	0.43	0.75
	Control discharge water	7.8	0.22	0.81
	Treated discharge water	8.9	0.28	0.76

Table 6.2 Average measurements of oxygen (O_2), salinity, temperature and pH

Test cycle	Water type	O_2 (%)	Salinity (PSU)	Temperature (°C)	pH
Test#1	Inlet water	99.5	34.0	20.0	7.9
	Control discharge water	100.8	34.1	20.7	7.9
	Treated discharge water	105.0	33.7	20.6	7.9
Test#2	Inlet water	99.0	34.4	19.5	7.9
	Control discharge water	95.8	34.4	21.1	7.9
	Treated discharge water	103.2	34.6	20.8	7.9
Test#3	Inlet water	96.8	37.1	23.9	8.2
	Control discharge water	101.0	37.3	24.6	8.3
	Treated discharge water	104.5	37.3	24.4	8.2

PSU Practical salinity units

6.2 Biological parameters

The densities of live organisms in the inlet and control discharge water were in accordance with the IMO G8 guidelines (IMO 2008) in all test cycles. Detailed data from the biological efficacy analyses are available in Appendix A.

6.2.1 Organism size class ≥50 µm

The densities of viable organisms in the ≥50 µm size class varied from approximately 4,900 to approximately 10,000 organisms per m3 in the inlet water and from 579 to approximately 2,000 organisms per m3 in the control discharge water (Table 6.3). The organisms in the ≥50 µm size class were primarily identified as copepods and nauplii.

Table 6.3 Total sample volumes and average concentrations of viable organisms in the size class ≥50 µm. Specific data and individual sample volumes available in Appendix A.

Water type	Inlet water		Control discharge water		Treated discharge water	
	Total sample volume (m^3)	Organ-isms/m^3	Total sample volume (m^3)	Organ-isms/m^3	Total sample volume (m^3)	Organ-isms/m^3
Test#1	3.73	4,892	4.42	579	9.76	0.17
Test#2	3.96	8,199	3.97	2,010	9.83	0.26
Test#3	4.50	9,983	4.50	1,347	10,43	0
IMO G8	>3	>90	>3	>10	>9	<10

In test cycles #1 and #2, the average numbers of viable organisms in the ≥50 µm size class were 0.17 and 0.26 per m^3 in the treated discharge water, which is approx. 40-60 times below the threshold value defined in the IMO D-2 standard. In test cycle #3, no viable organisms in the ≥50 µm size class were observed.

6.2.2 Organism size class ≥10 and <50 µm

The average densities in the inlet water were 94-127 organisms/mL when determined by inverted microscopy. The MPN in inlet water and control discharge water varied from >150 to >160 in test cycles #1 and #2. In test cycle #3, the MPN in inlet water was 54 organisms/mL and 46 organisms/mL in control discharge water. The reason for the higher density of organisms obtained by microscopy compared with the MPN in the inlet water in test cycle #3 was probably that the majority of the organisms in the ≥10 and <50 µm size class enumerated by microscopy were non-photosynthetic organisms (e.g. heterotrophic micro-zooplankton). The MPN assay is based on measurements of fluorescence, which is produced by photosynthetic organisms (algae).

The MPN of algae, representing the ≥10 and <50 µm size class, in the treated discharge water was below the MPN assay detection limit of 0.18 organisms/mL in all test cycles. The average densities of viable algae in the treated discharge water were thus more than 55 times below the IMO D-2 standard. The decrease in primary production of 99-100% during treatment in the BWMS confirmed that the treatment resulted in an immediate impact on the algal photosynthesis. The low concentrations of viable algae (<0.18 organisms/mL) determined by the MPN assay provide solid confidence that the total number of organisms ≥10 and <50 µm was below the IMO D-2 standard. The conclusion was supported by microscopy examination of the treated discharge water in test cycle #3 by use of the method in DHI SOP 30/1701, which showed that no heterotrophic micro-zooplankton ≥10 and <50 µm could be observed in the treated samples.

Table 6.4 Average concentrations of viable organisms in the size class ≥10 µm and <50 µm. The primary production decrease is expressed as the percentage reduction of the measured primary production in inlet water. Specific data are provided in Appendix A.

Test cycle	Water type	Microscopy ≥10 and <50 µm (organisms/mL)	MPN (organisms/ mL)	Primary production	
				DPM	Decrease (%)
Test#1	Inlet water	122	>150	2,892	99.2
	Control discharge water	-	>160	1,422	
	Treated discharge water	-	<0.18	21	
Test#2	Inlet water	127	>160	3,362	99.9
	Control discharge water	-	>160	577	
	Treated discharge water	-	<0.18	2.3	
Test#3	Inlet water	94	54	514	100
	Control discharge water	-	46	336	
	Treated discharge water	-	<0.18	0	
IMO G8	Inlet water	>90	-	-	-
	Control discharge water	-	>10	-	-
	Treated discharge water	-	<10	-	-

MPN Most probable number
DPM Disintegrations per minute

UV irradiation causes damage to the DNA in the cells and it may take several days before the cell membrane is disrupted and the enzyme activity stops (Stehouwer et al. 2010, Liltved et al. 2011, Liebich et al. 2012). Enumeration of algae by use of the MPN assay is directly related to growth over a certain time period. The ability of algal species to grow is the meaningful definition of viability in an evaluation, of which the target is to determine the efficiency of treatment aiming to reduce the species in ballast water capable to proliferate and survive in the natural environment. For UV treatment systems, the MPN assay is considered the best available methodology for evaluation of viable algae. Primary production analyses provide a measure for algal photosynthesis by determining amounts of ^{14}C fixed by photosynthesis. Neither the MPN assay nor primary production analyses are limited to the ≥10 and <50 µm size class; on the contrary, these parameters include planktonic algae without reference to size.

6.2.3 Bacteria

For shipboard testing, there are no requirements in the IMO G8 guidelines (IMO 2008) in relation to the density of bacteria in the inlet water or the control discharge water.

Table 6.5 Average bacterial concentrations. Specific data available in Appendix A.

Test cycle	Water type	*E. coli* (CFU/100 mL)	Enterococci (CFU/100 mL)	*Vibrio cholerae* (CFU/100 mL)
Test#1	Inlet water	<10	120	<1
	Control discharge water	800	280	<1
	Treated discharge water	<10	<10	<1
Test#2	Inlet water	130	21	<1
	Control discharge water	14	<10	<1
	Treated discharge water	<10	<10	<1
Test#3	Inlet water	<10	<10	<1
	Control discharge water	<10	<10	<1
	Treated discharge water	<10	<10	<1
IMO G8	Inlet water	-	-	-
	Control discharge water	-	-	-
	Treated discharge water	<250	<100	<1

CFU Colony-forming units

In test cycle #1, the concentrations of *E. coli* and enterococci were higher in control discharge water compared to those in the inlet water. This was especially evident for *E. coli*, which was not detected in the inlet water. The probable explanation is contamination with *E. coli* in the vessel's ballast tank or piping system. In the treated discharge water, the average concentrations of *E. coli* and enterococci were below the detection limit in all test cycles.

After inspection of colonies on agar plates, three colonies from control inlet and control discharge water in test cycles #1 and #2 were sent to DTU Food for verification of *Vibrio cholerae*. None of the three colonies were *Vibrio cholerae* and, thus, *Vibrio cholerae* was not detected in any water sample in the shipboard test.

7 Conclusion

The ability of the DOG P40-300 to (a) successfully treat ballast water without interruption and (b) meet IMO D-2 ballast water discharge standard was evaluated during a series of three consecutive valid test cycles.

The average densities of viable organisms in the ≥50 µm size class varied from approx. 4,900 to approx. 10,000 organisms per m^3 in the inlet water. For the size class ≥10 and <50 µm, the average densities in inlet water varied from 94 to 127 organisms/mL when determined by inverted microscopy. The contents of *E. coli* and enterococci in the inlet water were <10-130 and <10-120, respectively. The inlet water concentrations of organisms ≥50 µm and the smaller planktonic organisms (≥10 and <50 µm) fulfilled the validity criteria defined in the IMO G8 guidelines (IMO 2008).

The numbers of viable organisms in the ≥50 µm size class were 0.17, 0.26 and 0 per m^3 in the three test cycles, which is at least 40 times below the threshold value defined in the IMO D-2 standard (IMO 2004). In all three test cycles, the average density of viable algae in the treated

discharge water was determined to be <0.18 organisms/mL by use of the MPN assay. The average density of viable algae in the treated discharge water was thus more than 55 times below the IMO D-2 standard. Measurements of primary production showed a decrease of 99-100% after treatment in the BWMS compared with the control with untreated ballast water, which confirmed that the treatment resulted in an immediate impact on the algal photosynthesis. In the treated discharge water, the average concentrations of *E. coli* and enterococci were below the detection limit in all test cycles. *Vibrio cholerae* was not detected in any water sample in the shipboard test.

The DOG P40-300 functioned properly during all three test cycles and was highly effective at reducing live organism densities under the shipboard testing conditions. The densities of live organisms in the size classes and the densities of specific bacteria defined in the IMO G8 guidelines were below the IMO D-2 standard in the treated discharge water in all test cycles. All three test cycles were considered to fulfil the validity criteria of the IMO G8 guidelines.

8 References

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APPENDIX A

Detailed data on physical and chemical properties and biological efficacy analyses in shipboard testing of DOG P40-300

Physical-chemical parameters

Table A.1 Measurements of total suspended solids (TSS)

Test cycle	Water type	TSS (mg/L)				
		FR1	FR2	FR3	AVG	STD
Test#1	Inlet water	81	53	45	**59**	±19
	Control discharge water	15	16	15	**15**	±0.38
	Treated discharge water	14	13	14	**14**	±0.77
Test#2	Inlet water	43	67	33	**48**	±18
	Control discharge water	4.2	3.9	4.0	**4.0**	±0.17
	Treated discharge water	4.7	3.3	3.2	**3.7**	±0.80
Test#3	Inlet water	13	9.6	10	**11**	±1.7
	Control discharge water	8.7	8.0	6.5	**7.8**	±1.1
	Treated discharge water	9.7	8.7	8.2	**8.9**	±0.79

FR Field replicate
AVG Average
STD Standard deviation

Table A.2 Measurements of particulate organic carbon (POC)

Test cycle	Water type	POC (mg/L)				
		FR1	FR2	FR3	AVG	STD
Test#1	Inlet water	1.6	1.2	1.1	**1.3**	±0.29
	Control discharge water	0.78	0.78	0.77	**0.77**	±0.002
	Treated discharge water	0.58	0.47	0.60	**0.55**	±0.07
Test#2	Inlet water	1.2	1.6	0.9	**1.2**	±0.37
	Control discharge water	0.61	0.69	0.58	**0.62**	±0.06
	Treated discharge water	0.42	0.44	0.50	**0.45**	±0.04
Test#3	Inlet water	0.53	0.28	0.49	**0.43**	±0.13
	Control discharge water	0.08	0.20	0.39	**0.22**	±0.16
	Treated discharge water	0.19	0.31	0.34	**0.28**	±0.08

FR Field replicate
AVG Average
STD Standard deviation

Table A.3 Measurements of dissolved organic carbon (DOC)

Test cycle	Water type	DOC (mg/L)				
		FR1	FR2	FR3	AVG	STD
Test#1	Inlet water	0.69	0.69	0.67	**0.68**	±0.01
	Control discharge water	0.62	0.61	0.64	**0.62**	±0.02
	Treated discharge water	0.69	0.81	0.69	**0.73**	±0.07
Test#2	Inlet water	0.58	0.59	0.74	**0.64**	±0.09
	Control discharge water	0.55	0.42	0.57	**0.51**	±0.08
	Treated discharge water	0.65	0.66	0.59	**0.63**	±0.04
Test#3	Inlet water	0.78	0.83	0.64	**0.75**	±0.10
	Control discharge water	0.95	0.82	0.67	**0.81**	±0.14
	Treated discharge water	0.85	0.72	0.72	**0.76**	±0.07

FR Field replicate
AVG Average
STD Standard deviation

Organism size class ≥50 µm

Table A.4 Enumeration of organisms ≥50 µm and sample volumes

Test cycle	Water type	Organisms ≥50 µm							
		FR1		FR2		FR3		AVG	STD
		vol. m³	org./m³	vol. m³	org./m³	vol. m³	org./m³		
Test #1	Inlet water	1.22	4,150	1.25	3,240	1.26	7,286	**4,892**	±2,123
	Control discharge water	1.64	390	1.40	768	1.38	-*	**579**	±267
	Treated discharge water	3.35	0	3.18	0.26	3.23	0.26	**0.17**	±0.15
Test #2	Inlet water	1.33	7,476	1.34	6,888	1.29	10,233	**8,199**	±1,786
	Control discharge water	1.30	2,319	1.37	2,323	1.30	1,389	**2,010**	±538
	Treated discharge water	3.27	0.52	3.26	0.26	3.30	0	**0.26**	±0.26
Test #3	Inlet water	1.50	8,800	1.50	11,550	1.50	9,600	**9,983**	±1,415
	Control discharge water	1.50	1,511	1.50	1,248	1.50	1,283	**1,347**	±143
	Treated discharge water	3.43	0	3.51	0	3.49	0	**0**	-

FR Field replicate
AVG Average
STD Standard deviation
* Sample lost

Organism size class ≥10 and <50 µm

Table A.5 Enumeration of organisms ≥10 µm and <50 µm by microscopy

Test cycle	Water type	≥10 µm and <50 µm (organisms/mL)										
		FR1	FR2	FR3	FR4	FR5	FR6	FR7	FR8	FR9	AVG	STD
Test#1	Inlet	139	116	111	-	-	-	-	-	-	**122**	±15
Test#2	Inlet	129	184	68	-	-	-	-	-	-	**127**	±58
Test#3	Inlet	129	82	71	-	-	-	-	-	-	**94**	±31
	Treated discharge	0	-	-	0	-	-	0	-	-	0	-

FR Field replicate
AVG Average
STD Standard deviation

Table A.6 Determination of viable algae by the most probable number (MPN) assay

Test cycle	Water type	Viable algae (organisms/mL)										
		FR1	FR2	FR3	FR4	FR5	FR6	FR7	FR8	FR9	AVG	STD
Test#1	Inlet	>160	>140	>160	-	-	-	-	-	-	**>150**	-
	Control discharge	>160	>160	>160	-	-	-	-	-	-	**>160**	-
	Treated discharge	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	**<0.18**	-
Test#2	Inlet	>160	>160	>160	-	-	-	-	-	-	**>160**	-
	Control discharge	>160	>160	>160	-	-	-	-	-	-	**>160**	-
	Treated discharge	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	**<0.18**	-
Test#3	Inlet	35 (12-100)	92 (29-290)	35 (12-100)	-	-	-	-	-	-	**54**	**±33**
	Control discharge	24 (8,9-64)	92 (29-290)	22 (8,3-59)	-	-	-	-	-	-	**46**	**±40**
	Treated discharge	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	**<0.18**	-

FR Field replicate
AVG Average
STD Standard deviation
( ) 95% confidence interval

Table A.7 Measurements of primary production by planktonic algae

Test cycle	Water type	Primary production (DPM)										
		FR1	FR2	FR3	FR4	FR5	FR6	FR7	FR8	FR9	AVG	STD
Test#1	Inlet	3,282	3,105	2,288	-	-	-	-	-	-	**2,892**	±530
	Control discharge	1,495	1,320	1,450	-	-	-	-	-	-	**1,422**	±91
	Treated discharge	19	-	-	23	-	-	21	-	-	**21**	±2.1
Test#2	Inlet	3,359	3,623	3,104	-	-	-	-	-	-	**3,362**	±260
	Control discharge	582	606	542	-	-	-	-	-	-	**577**	±32
	Treated discharge	1.9	-	-	4.9	-	-	0	-	-	**2.3**	±2.5
Test#3	Inlet	497	482	562	-	-	-	-	-	-	**514**	±43
	Control discharge	335	349	323	-	-	-	-	-	-	**336**	±13
	Treated discharge	0	-	-	0	-	-	0	-	-	**0**	-

DPM Disintegrations per minute
FR Field replicate
AVG Average
STD Standard deviation

Bacteria

Table A.8 Enumeration of *E. coli*

Test cycle	Water type	*E. coli* (CFU/100 mL)										
		FR1	FR2	FR3	FR4	FR5	FR6	FR7	FR8	FR9	AVG	STD
Test#1	Inlet	<10	<10	<10	-	-	-	-	-	-	**<10**	-
	Control discharge	<10	500	1,900	-	-	-	-	-	-	**800**	±980
	Treated discharge	<10	<10	<10	<10	<10	<10	<10	<10	<10	**<10**	-
Test#2	Inlet	<10	10	360	-	-	-	-	-	-	**130**	±200
	Control discharge	<10	<10	21	-	-	-	-	-	-	**14**	±6.4
	Treated discharge	<10	<10	<10	<10	<10	<10	<10	<10	<10	**<10**	-
Test#3	Inlet	<10	<10	<10	-	-	-	-	-	-	**<10**	-
	Control discharge	<10	<10	<10	-	-	-	-	-	-	**<10**	-
	Treated discharge	<10	<10	<10	<10	<10	<10	<10	<10	<10	**<10**	-

CFU Colony-forming units
FR Field replicate
AVG Average
STD Standard deviation

Table A.9 Enumeration of enterococci

Test cycle	Water type	Enterococci (CFU/100 mL)										
		FR1	FR2	FR3	FR4	FR5	FR6	FR7	FR8	FR9	AVG	STD
Test#1	Inlet	21	160	190	-	-	-	-	-	-	**120**	±90
	Control discharge	32	130	670	-	-	-	-	-	-	**280**	±340
	Treated discharge	<10	<10	<10	<10	<10	<10	<10	<10	<10	**<10**	-
Test#2	Inlet	10	32	21	-	-	-	-	-	-	**21**	±11
	Control discharge	<10	<10	<10	-	-	-	-	-	-	**<10**	-
	Treated discharge	<10	<10	<10	<10	<10	<10	<10	<10	<10	**<10**	-
Test#3	Inlet	<10	<10	<10	-	-	-	-	-	-	**<10**	-
	Control discharge	<10	<10	<10	-	-	-	-	-	-	**<10**	-
	Treated discharge	<10	<10	<10	<10	<10	<10	10	<10	<10	**<10**	-

CFU Colony-forming units
FR Field replicate
AVG Average
STD Standard deviation

Table A.10 Enumeration of *Vibrio cholerae*

Test cycle	Water type	*Vibrio cholerae* (CFU/100 mL)										
		FR1	FR2	FR3	FR4	FR5	FR6	FR7	FR8	FR9	AVG	STD
Test#1	Inlet	<1	<1	<1	<1	<1	<1	<1	<1	<1	**<1**	-
	Control discharge	<1	<1	<1	<1	<1	<1	<1	<1	<1	**<1**	-
	Treated discharge	<1	<1	<1	<1	<1	<1	<1	<1	<1	**<1**	-
Test#2	Inlet	<1	<1	<1	<1	<1	<1	<1	<1	<1	**<1**	-
	Control discharge	<1	<1	<1	<1	<1	<1	<1	<1	<1	**<1**	-
	Treated discharge	<1	<1	<1	<1	<1	<1	<1	<1	<1	**<1**	-
Test#3	Inlet	<1	<1	<1	<1	<1	<1	<1	<1	<1	**<1**	-
	Control discharge	<1	<1	<1	<1	<1	<1	<1	<1	<1	**<1**	-
	Treated discharge	<1	<1	<1	<1	<1	<1	<1	<1	<1	**<1**	-

CFU Colony-forming units
FR Field replicate
AVG Average
STD Standard deviation

APPENDIX B

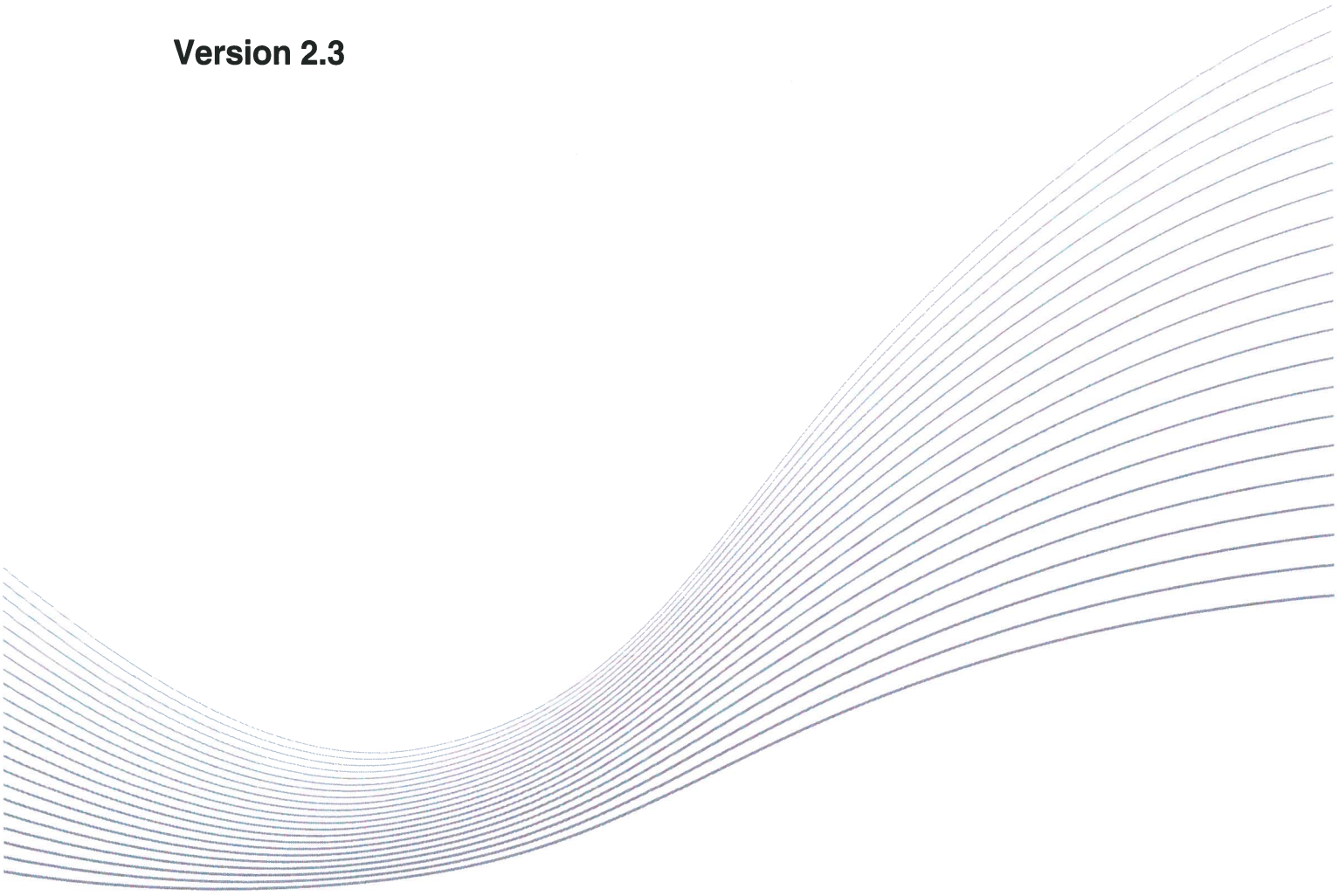
Quality Management Plan (QMP) and revised Quality Assurance Project Plan (QAPP) with Amendment No. 1 and Deviation No. 1

Quality Management Plan

Performance Evaluation of Ballast Water Management Systems

DHI Denmark

Version 2.3



WATER • ENVIRONMENT • HEALTH

September 2011

Quality Management Plan

Performance Evaluation of Ballast Water Management Systems

DHI Denmark
Version 2.3

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Project	Project No.
Quality Management Plan Performance Evaluation of Ballast Water Management Systems DHI Denmark Version 2.3	
Author Gitte I. Petersen	Date 2011.09.07
	Approved by Torben Madsen

Revision	Description	By	Checked	Approved	Date
2.3	QMP	GIP	TMA	TMA	7/9-11

Key words	Classification
	☐ Open ☐ Internal ☒ Proprietary

Distribution	No. of copies
Client Certification body DHI: /EAT	

CONTENTS

APPENDICES

1 TERMS AND ABBREVIATIONS

Terms/Abbreviations	Definitions and comments
Active substance	A substance which has a general or specific action on aquatic organisms or bacteria (pathogens)
Ballast Water Management System (BWMS)	A system which removes, renders harmless or avoids uptake or discharge of aquatic organisms and bacteria (pathogens) with ballast water and sediments by mechanical, physical, chemical or biological means acting individually or in combination
Certification Body	Body to certify facilities to conduct performance evaluation of BWMS according to the IMO Convention
Client	The party requesting a performance evaluation of a technology.
Convention	The IMO convention on ballast water
International Maritime Organization (IMO)	United Nations specialized agency with responsibility for the safety and security of shipping and the prevention of marine pollution by ships Comment: IMO has adopted the International Convention for the Control and Management of Ship's Ballast Water and Sediments
Quality Assurance Project Plan (QAPP)	Project-specific technical document describing the BWMS to be tested, the test facility and other conditions affecting the actual design and implementation of the required experiments
Quality Management Plan (QMP)	Generic document describing the quality control management structure and policies of the testing body (including subcontractors and outside laboratories)
Services	The performance evaluation of maritime technologies by laboratory, land-based or shipboard tests or a combination hereof
Standard Operation Procedure (SOP)	Generic document providing rules, guidelines or characteristics for tests or analyses Comment: In-house methods may be used in the absence of a recognized standard, if they are commonly accepted for testing of BWMS or scientifically documented

2 INTRODUCTION

The International Maritime Organization (IMO) has adopted the International Convention for the Control and Management of Ship's Ballast Water and Sediments /1/ to reduce the risk of spreading of harmful aquatic organisms and pathogens released with ballast water.

The Convention requires that all ships comply with specified water quality requirements (D2) before ballast water is released into the environment.

The performance evaluation of ballast water management systems (BWMS) aims at documenting compliance with the requirements stated in international guidelines, e.g.:

- Guideline for approval of ballast water management systems - G8 /2/

- Procedure for approval of ballast water management systems that make use of active substances - G9 /3/.

DHI provides services in relation to performance evaluation of maritime technologies and particularly BWMS within the DHI Ballast Water Centre which includes test facilities and laboratories in Denmark and Singapore.

The DHI Ballast Water Centre is organized with a Ballast Water Facility Board including two members from the management in DHI Denmark and two members from the management in DHI Singapore. The object of the Board is to coordinate the development and marketing of services related to the performance evaluation of BWMS within the DHI Group.

The services addressed with the present Quality Management Plan (QMP) include:

- Laboratory tests conducted at the DHI environmental laboratory in Hørsholm, Denmark, aiming at proof-of-concept or technology optimisation
- Pilot-tests conducted at the DHI Maritime Technology Evaluation Facility (hereafter referred to as the "test facility") in Hundested, Denmark, aiming at technology optimisation
- Land-based tests conducted at the test facility according to international guidelines
- Shipboard tests conducted by DHI Denmark according to international guidelines at vessels, on which the technology is installed

The above activities are collectively referred to as the "services" whereas individual activities are referred to as "projects".

The aim of the services is to provide independent, third party documentation for the performance of maritime technologies. High quality of the services is ensured through extensive quality management and use of skilled staff.

3 ORGANISATION

3.1 Head of department (Torben Madsen)

The head of department, business strategy, for DHI's Department of Environment and Toxicology, has the overall responsibility for the services and the test facility. This includes the following tasks:

- Co-ordination of joint business development between DHI Denmark and DHI Singapore via participation in the Ballast Water Facility Board
- Negotiation of agreements (i.e. service contracts) with clients
- Responsibility for overall co-ordination, planning and costs as required to ensure that the appropriate human resources, facilities and equipment are available for the services
- Appointment of the business area manager, the project manager and task leaders for cross-cutting functions (e.g. production of test water and test facility technical operations)
- Maintenance of the QMP with updated versions as appropriate

- Approval of the Quality Assurance Project Plan (QAPP) and Standard Operation Procedures (SOPs)
- Quality control and approval of test reports (provided that the head of department has not contributed to the technical solution of the project)
- Documentation in relation to

    - Staff training and experience
    - Facilities and their maintenance
    - Records of complaints

3.2 Business area manager (Gitte I. Petersen)

The business area manager is responsible for the scientific and technical quality of the services in co-ordination with the head of department. This includes the following managerial tasks:

- Business development and marketing
- Maintenance of generic standards that can serve as formats for drafting the QAPPs and approval of the methods applied in land-based and shipboard tests
- Dialogue with task leaders for cross-cutting functions, e.g. production of test water and test facility technical operations
- Contributions to data interpretation and reporting of land-based and shipboard tests in collaboration with the project manager
- Participation in discussions with the Certification Body on important matters, particularly draft and final reports, together with the project manager
- Co-ordination of the services with the aim to ensure feasibility of parallel projects conducted at the test facility, including decisions related to the functioning of the test facility (e.g. piping and pumps)
- Maintenance of the test facility, connection piping between the test facility and the client's technology, and dialogue with academic and technical staff in order to fulfil DHIs responsibility for operating the test facility during testing
- Quality control of test reports (provided that the business area manager has not contributed to the technical solution of the project)

3.3 Project manager

The project manager is responsible for the management and efficient performance of the project in accordance with the contract between the client and DHI, the QMP and the QAPP.

The project manager's tasks include:

- Organisation and management of the project
- Periodic meetings and other communication with the client to ensure that all necessary information is available in due time
- Preparation of the draft and final QAPP with detailed description of the project, including time schedule and quality assurance of deliverables

- Facilitation of the process for comments and responses to the draft QAPP in dialogue with the client and the Certification Body
- Preparation of amendments and deviations to the QAPP, if any
- Communication of the project time schedule to the Certification Body to enable external audit
- Communication of the QAPP and project time schedule to the internal auditor identified in the QAPP to enable internal audit
- Participation in discussions with the Certification Body on important matters, particularly draft and final reports, together with the business area manager
- Co-ordination and dialogue with the business area manager in relation to safe conditions of work, logistics and technical operations at the test facility
- Co-ordination and dialogue with the laboratory manager in relation to the practical organisation of work involving laboratory technicians; the project manager shall in due time inform the laboratory manager on the types of tests and the required capacity to enable laboratory capacity planning
- Agreements with subcontractors as appropriate for meeting the project deliverables (e.g. chemical analytical laboratory)
- Approval of initiation of the test cycles and interruption of test cycles, e.g. in case of irregularity
- Preparation of reports

3.4 Head of projects

The academic staff (with exception of the business area manager, project manager, task leaders for cross-cutting functions and test co-ordinators) and the secretaries are appointed by the head of projects via dialogue with the business area manager or the project manager as appropriate.

3.5 Laboratory manager

The laboratory manager appoints laboratory technicians for a specific project and allocates tasks to them as part of the laboratory capacity planning. Furthermore, the laboratory manager appoints one or more test co-ordinators among the laboratory technicians or the academic staff for on-site co-ordination of land-based test cycles.

3.5.1.1 Academic staff, laboratory technicians and secretaries

The tasks of the academic staff, the laboratory technicians and the secretaries include:

- Contributions to the QMP, QAPP and SOPs
- Test co-ordinator function, i.e. co-ordination and keeping timely records of the activities at the test facility during land-based tests
- Sampling at the test facility
- Monitoring of test water quality
- Maintenance of materials and equipment
- Analysis and data processing
- Contributions to test reports

- Archiving of documents and raw data

4 PERFORMANCE OF PROJECT

4.1 Agreement

An agreement between the client and DHI is negotiated and signed according to the DHI manual for project management.

4.2 Quality Assurance Project Plan (QAPP)

The QAPP is a project specific document describing the technology to be tested, the test facility, and other conditions affecting the actual design and implementation of the study. The QAPP is only required for performance evaluation of BWMS in land-based or shipboard tests conducted according to international guidelines.

The QAPP is

- Prepared by the project manager
- Signed by the project manager, the head of department and the internal auditor from the DHI Quality Assurance Unit
- Forwarded to the Certification Body for review and comments
- Forwarded to the client for review, acceptance and signature.

The QAPP typically includes the following titles:

1. Objective
2. Client (including client's monitor, if any)
3. Administration
4. DHI Ballast Water Centre
5. Subcontractors
6. Project management
7. System description
8. Safety handling of active substances
9. Test design (including, for **land-based test**, test cycles, test water, sampling and analyses, and, for **shipboard test**, trial period and locations, sampling and analyses)
10. Validity criteria
11. Pass criteria
12. Time schedule
13. Quality assurance
14. Report
15. Archiving
16. Amendments and deviations, if any
17. References

The QAPP refers to a number of SOPs (see Appendix A).

Amendments and deviations to the QAPP are approved and signed by the project manager. Amendments describe planned changes whereas deviations describe unplanned changes to the QAPP.

The QAPP is subject to internal audit in accordance with the procedures for internal audit of the DHI Quality Management System.

4.3 Services

The project will be conducted as described in the QAPP and subsequent amendments and deviations or, alternatively, as described in the agreement between the client and DHI for projects, for which no QAPP is prepared.

4.3.1 Laboratory tests

Laboratory tests can be initiated when the BWMS technology is ready for testing and DHI's deliverables are defined. Initiation of testing is decided by the project manager in agreement with the client.

4.3.2 Pilot tests

Pilot tests can be initiated when the BWMS technology is installed and ready for operation. Initiation of testing is decided in consensus by and between the business area manager and the project manager in agreement with the client.

4.3.3 Land-based tests

Land-based tests can be initiated when the BWMS technology is installed and ready for operation. Initiation of testing is decided in consensus by and between the business area manager and the project manager in agreement with the client.

The project manager decides when a test cycle in the land-based test is completed and valid, when appropriate by reference to the G8 guidelines /2/, G9 guidelines /3/ or other standards (e.g. US requirements). If required, the project manager can decide to interrupt a test cycle due to technical malfunctioning of the test facility or the BWMS, insufficient state of biological or physical parameters or for other reasons related to the quality of the test water.

4.3.4 Shipboard tests

Shipboard testing can be initiated when the BWMS technology is installed on the vessel and ready for operation. Initiation of testing is decided by the project manager in agreement with the client.

The project manager decides when a test cycle in the shipboard test is completed and valid by reference to the criteria in G8 /2/ or, if appropriate, to criteria in other standards (e.g. US requirements). If required, the project manager can decide to interrupt a test cycle due to technical malfunctioning of the BWMS, insufficient state of biological or physical parameters or for other reasons related to the water quality.

4.4 Reports

Reports are prepared with the details, format and language described in the agreement between the client and DHI.

4.4.1 Performance evaluation of BWMS under the IMO convention

For land-based or shipboard tests of BWMS conducted as part of the IMO approval process, the report is typically structured by use of the appropriate headings in the QAPP and shall include a summary of any amendments and deviations to the QAPP.

The report shall include all relevant technical and analytical data and will contain at least the following items:

- Name and address of the client (and monitor, if any)
- Name and address of the testing facility and the dates, on which the test was initiated and completed
- Objectives and procedures stated in the approved QAPP including any changes made to the QAPP
- Results obtained, presented in summarizing tables and as raw data
- Any unforeseen circumstances which may have affected the quality or integrity of the land-based/shipboard testing
- Storage locations of all raw data, the signed QAPP and report
- Descriptions of operations, calculations and transformations performed on the presented data
- Quality assurance statement

The report shall be signed by the project manager, the internal auditor from the DHI Quality Assurance Unit and the head of department.

The final report will be prepared in English and forwarded to the client.

5 QUALITY MANAGEMENT PROCESSES

5.1 DHI Quality Assurance

The services are conducted in accordance with the principles of ISO 9001 by using the DHI Quality Manual and the procedures in this QMP. The Quality Management System of DHI is found compliant with ISO 9001 as part of the ISO 17025 accreditation of the DHI environmental laboratory.

The DHI quality manager is responsible for assigning a trained internal auditor from DHI's Quality Assurance Unit to each project in accordance with the procedures for internal audit of the DHI Quality Management System.

The internal auditor is identified in the QAPP. The internal auditor shall receive the QAPP from the project manager in order to plan and execute internal audit of the project.

5.2 Document and record control

The DHI Quality Manual includes a procedure describing the process of drafting, revising and approving documentation. Standard operation procedures are controlled as described in SOP 30/944.

SOPs 30/921 and 30/937 describe how records of the test are stored, transferred, maintained and controlled in order to ensure data integrity for a period defined in the QAPP, but not shorter than 5 years from completion of the verification.

5.3 Internal audits

Procedure 3 in the DHI Quality System Manual on audit and evaluation and SOP 30/943 describe the process of periodic internal auditing of projects and activities including audit responsibilities and planning, auditor training and competences and audit reporting.

Procedure 4 in DHI Quality System Manual on non-conformities and corrective actions describes how deviations identified during operation and auditing are corrected (corrective actions) and how future occurrence of the same deviations is prevented by improving the quality manual including the process descriptions and working methods (preventive actions).

5.4 Complaint management

Procedure 5 in the DHI Project Management Manual on Complaints describes how complaints are recorded, resolved and reported. If not resolved, complaints are referred to the Certification Body for resolving.

5.5 Subcontractor management

Procedure 4 in the DHI Project Management Manual on subcontractors describes how it is ensured that subcontractors follow quality requirements.

In addition, analytical laboratories providing analyses of any kind should:

- Maintain an ISO 17025 accreditation with the quality management system required herein.
- Apply accredited analytical methods when available.
- Apply other methods according to either international standard methods or in-house methods that are in all cases validated as required for accredited methods.

SOP 30/700 furthermore describes how it is ensured that purchased items such as chemicals and glassware are controlled, accepted and calibrated.

5.6 Staff competence management

Procedure 3 on appraisal interview, post qualifying education and experience in the DHI Employee Conditions Handbook describes how it is ensured that the projects are conducted by staff with adequate competences and knowledge. This is done by maintaining a list of functions in the test process with competence requirements and responsibilities. The list is supported by reference to staff files in the DHI CV database.

5.7 Facility management

SOP 30/945 describes how it is ensured that facilities and equipment are available and fit for the purposes.

5.8 Management review

Procedure 3 of the Quality System Manual on audit and evaluation describes how the DHI management is ensuring that the test centre is working according to this quality manual through mechanisms such as e.g. an annual management review process.

The Quality Manager is responsible for maintenance and development of the quality system and for the internal auditing of all aspects of the system – with daily reference to the Director, Group R&D and Quality Management. The DHI Quality Manual contains rules for reviews of the quality system.

6 REFERENCES

/1/ IMO (2005): International Convention for the Control and Management of Ships Ballast Waterand Sediments. London. International Maritime Organization.

/2/ MEPC. Guidelines for approval of ballast water management systems (G8). resolution MEPC.174(58). Adopted 10th October 2008.

/3/ MEPC. Procedure for approval of ballast water management systems that make use of active substances (G9). MEPC.126(53) Adopted 22nd July 2005.

A P P E N D I X A

BMWS testing-specific Standard Operating Procedures (SOPs)

SUBJECT/SUBSUBJECT	NO.
ANALYTICAL METHOD ZOOPLANKTON ANALYSIS	30/1700:04
ANALYTICAL METHOD MICROSCOPIC ENUMERATION AND IDENTIFICATION OF MICROALGAE (LUGOL AND CMFDA/FDA)	30/1701:02
ANALYTICAL METHOD DETERMINING PRIMARY PRODUCTION OF MICROALGAE	30/1702:03
ANALYTICAL METHOD DETERMINING DIVERSITY OF MICROALGAL COMMUNITIES BY HPLC ANALYSIS OF PIGMENTS	30/1703:03
ANALYTICAL METHOD DETERMINATION OF VIABLE ALGAE BY MPN	30/1704:02
MICROBIOLOGICAL TESTS DETERMINATION OF TOTAL NUMBER OF BACTERIA BY EPIFLUORESCENCE MICROSCOPY	30/1705:03
MICROBIOLOGICAL TESTS DETERMINATION OF HETEROTROPHIC PLATE COUNT	30/1706:03
MICROBIOLOGICAL TESTS DETERMINATION OF *VIBRIO CHOLERAE* IN WATER	30/1707:02
MICROBIOLOGICAL TESTS DETERMINATION OF TOTAL COLIFORM, *E.COLI* AND ENTEROCOCCI Colilert*-18 AND Enterolert-E	30/1708:02
MEASUREMENT METHOD OZONE MEASUREMENT IN WATER	30/1730:02
MEASUREMENT METHOD OZONE MEASUREMENT IN AIR	30/1731:02
MEASUREMENT METHOD TRO MEASUREMENT IN WATER	30/1732:02
HARVESTING, CULTURING AND ADDITION OF ORGANISMS	30/1734:03
COLLECTION OF SEAWATER	30/1735:02
COLLECTION OF FRESH WATER	30/1736:02
CHEMICAL CRITERIA FOR TEST WATER ADDITION OF DOC, POC AND MM	30/1737:02
SAMPLING BIOLOGICAL AND WATER QUALITY PARAMETERS	30/1738:02
SAMPLING WET TEST	30/1739:02
SAMPLING DBP ANALYSIS	30/1740:02
STATISTICS STATISTICAL SURVEILLANCE OF BIOLOGICAL DATA OBTAINED AT TESTS OF BWMSs	30/1760:01
LABELLING SAMPLES COLLECTED AT TEST SITE	30/1761:01
OPERATION OF THE DHI MTEF	30/1762:02
CLEANING RETENTION TANKS, PIPINGS AND OTHER EQUIPMENT AT TEST SITE	30/1763:02
MEASUREMENT METHOD ON-LINE MONITORING OF PRESSURE, TEMPERATURE AND FLOW RATES AT TEST SITE	30/1764:01
MEASUREMENT METHOD FLUORESCENCE	30/1765:02

SUBJECT/SUBSUBJECT	NO.
MEASUREMENT METHOD TURBIDITY	30/1766:03
HEALTH AND SAFETY ENSURING WORKER HEALTH AND SAFETY AT TEST SITE	30/1767:02
MEASUREMENT METHOD DETERMINATION OF TSS	30/1768:02
MEASUREMENT METHOD DETERMINATION OF DOC AND POC	30/1769:02

APPENDIX B

Overview of lists

Overview of lists

The lists mentioned below are kept together with the rest of quality documentation.

Certification Body

DHI holds a statement describing the Certification Body that has certified the DHI Maritime Technology Evaluation Facility.

List of sub-contractors

DHI keeps a list of sub-contractors used during the test. The list contains information on name of company, address, contact person, e-mail, telephone number and deliveries.

List of staff approved for functions at the test facility

DHI keeps a list of persons working at the test facility. The list contains information on the person's activities, responsibility and documentation for training. The person's competence is documented in an available CV.

List of Standard Operation Procedures

DHI keeps a list of SOPs, including those used in relation to projects conducted at the test facility.

APPENDIX C

Template for amendments to QAPP

AMENDMENT

QAPP DOCUMENT TITLE AND DATE:

AMENDMENT NUMBER:

DATE OF AMENDMENT:

AMENDMENT CONTENTS:

REASON FOR AMENDMENT:

IMPACT OF AMMENDMENT:

PREVENTATIVE ACTION:

If relevant, action to prevent that the same cause of amendment will reoccur in the future.

ORIGINATED BY:

SIGNED BY:

_____

Project manager

_____

DATE

Copy to be sent to the client, the Certification Body and the DHI Quality Assurance Unit.

APPENDIX D

Template for amendments to QAPP

DEVIATION

QAPP DOCUMENT TITLE AND DATE:

DEVIATION NUMBER:

DATE OF DEVIATION:

DESCRIPTION OF DEVIATION:

REASON FOR DEVIATION:

IMPACT OF DEVIATION:

CORRECTIVE ACTION:

If required, actions to be taken to prevent consequences of deviation

ORIGINATED BY:

SIGNED BY:

_____
Project manager

_____
DATE

Copy to be sent to the client, the Certification Body and the DHI Quality Assurance Unit.

REVISED

Quality Assurance Project Plan

Shipboard Test of DOG P40-300 Ballast Water Management System

September 2011

REVISED
Quality Assurance Project Plan

Shipboard Test of DOG P40-300 Ballast Water Management System

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Client	Client's representative
DESMI Ocean Guard A/S	Christian Ingvorsen

Project	Project No
Shipboard Test of DOG P40-300 Ballast Water Management System	11810704
Authors	**Date:**
Torben Madsen	2011.09.09
	Approved by
	Margrethe Winther-Nielsen

		TMA	GIP	MWN	
02	Revised QAPP	TMA	GIP	MWN	2011.09.09
01	QAPP	TMA	GIP	JET	2011.09.07
Revision	Description	By	Checked	Approved	Date

Key words	Classification
	☐ Open ☐ Internal ☒ Proprietary

Distribution	No of copies
DESMI Ocean Guard A/S Lloyds Register DHI	Electronic

CONTENTS

APPENDICES

1 OBJECTIVE

For an application for final approval, the IMO Convention requires an approval of Ballast Water Management Systems (BWMS) according to the principles laid down in Resolution MEPC.174(58) (G8) /1/ to assure that BWMS approved by administrations are capable of meeting the standard regulation D-2 (MEPC G8) in land-based and shipboard evaluations and do not cause unacceptable harm to the vessel, crew, environment or public health.

The objective is to conduct a shipboard test of the DOG P40-300 BWMS (hereafter DOG P40-300) according to Resolution MECP.174(58), Guidelines for approval of ballast water management systems (G8) (hereafter designated as the 'G8 guidelines').

2 CLIENT

DESMI Ocean Guard A/S
Lufthavnsvej 12
DK-9400 Nørresundby
Denmark

Contact person: Christian Ingvorsen

3 CERTIFICATION BODY

Lloyds Register, EMEA
Strandvejen 104 A, 2.
DK-2900 Hellerup

Contact person: Martin Schabert

4 DHI BALLAST WATER CENTRE

DHI
Agern Allé 5
DK-2970 Hørsholm
Denmark

Contact Person: Torben Madsen

5 SUBCONTRACTORS

The shipboard test will be conducted by DHI, and, with the possible exception of verification of *Vibrio cholerae* (according to SOP 30/1707), subcontractors will not be involved.

6 PROJECT MANAGEMENT

The project manager for the study is Head of Department Torben Madsen, M.Sc. (biology) and Ph.D. (environmental microbiology).

7 SYSTEM DESCRIPTION

The description of the DOG P40-300, provided in Appendix A, is identical to the description received from the client.

8 SAFETY HANDLING OF ACTIVE SUBSTANCES

The safety measures prescribed by DESMI Ocean Guard A/S (Appendix A) shall be observed during work onboard the vessel. The 40' container with the BWMS has exits in either end of the container. The rear exit is marked with emergency exit sign. One of the lights inside the container is connected to a battery, so in case of power loss there will still be light inside the container. In case loss of power to the container the UV lights will be also be switched off and ozone generation will also stop immediately.

9 TEST DESIGN

9.1 Trial period and locations

The shipboard test will include three test cycles conducted during at least two separate campaigns on board the container vessel Thuroe Maersk. The campaigns will be conducted within a trial period with a time span of not less than six months.

The campaigns that are planned to be conducted in ports in Portugal, Spain and Morocco facing the Atlantic Ocean.

The first campaign is scheduled to be conducted at locations in the regions mentioned above between 9 September and 20 September 2011.

The second campaign will be conducted in March 2012 or later. Details on dates and locations for ballasting and deballasting activities will be provided as amendments to the Quality Assurance Project Plan when this information is available.

9.2 Test cycles

The BWMS will be operated by DESMI Ocean Guard A/S during the three test cycles. Each test cycle consists of sampling and analyses of:

Inlet water (the physico-chemical and biological parameters in the inlet water will be considered as sufficiently stable during the ballasting; unless the local conditions indicate that the parameters in the inlet water vary with time, only one set of samples and analyses will be used to represent the control tank and the ballast tank);

Discharge control water (stored without treatment from the time of ballasting to discharge);

Discharge treated water (treated and stored from the time of ballasting to discharge).

9.3 Sampling

9.3.1 Sample overview

	Samples	Sample volumes per replicate
Inlet water	3 replicates	Organisms ≥50 µm: >1 m^3 *
		Organisms 10-50 µm: >1 L **
		Bacteria: >0.5 L **
		DOC + POC: approx. 0.5 L **
		TSS: approx. 2 L **
Discharge control water	3 replicates	Organisms ≥50 µm: >1 m^3 *
		Organisms 10-50 µm: >1 L **
		Bacteria: >0.5 L **
		DOC + POC: approx. 0.5 L **
		TSS: approx. 2 L **
Discharge treated water	3 replicates	Organisms ≥50 µm: >3 m^3 *
	3 x 3 replicates	Organisms 10-50 µm: >1 L **
	3 x 3 replicates	Bacteria: >0.5 L **
	3 replicates	DOC + POC: approx. 0.5 L **
	3 replicates	TSS: approx. 2 L **

*, collected by continuous flow during the entire period of intake or discharge; this continuous sampling of 3 replicates, each with a volume of at >3 m^3, provides the same statistical basis for counting as the sampling 3 x 3 replicates of >1 m^3 which is recommended in the G8 guidelines; **, grab samples collected over the period of intake or discharge (e.g. start, middle and end) .

9.3.2 Samples for enumeration of organisms ≥50 µm

Three replicates will be collected by parallel continuous sampling during the entire periods of intake and discharge. The samples will be gently filtered through a net with a mesh size of 35 µm and a reservoir (cod-end) at the bottom of the net for collecting the organisms ≥50 µm (zooplankton). Each replicate will be concentrated in 1-L glass bottles. The total volume of the filtered sample will be determined by a flow meter.

9.3.3 Samples for enumeration of organisms ≥10 µm and <50 µm

Grab samples (3 replicates for the inlet water, 3 replicates for the control discharge water, and 3 x 3 replicates for the treated discharge water) with a volume of at least 1 L will be collected in appropriate containers.

9.3.4 Samples for enumeration of bacteria

Grab samples (3 replicates for the inlet water, 3 replicates for the control discharge water, and 3 x 3 replicates for the treated discharge water) with a volume of at least 0.5 L will be collected in appropriate sterile containers.

9.4 Analyses

9.4.1 Analysis overview

	Temperature	Salinity	≥ 50 µm	10-50 µm, Lugol's	10-50 µm, MPN	10-50 µm, Primary production	Bacteria	DOC + POC	TSS
	Replicates								
Inlet water									
Replicate 1 (start)	1	1	Three replicates	1	1	1	1	1	1
Replicate 2 (mid)	2	2		2	2	2	2	2	2
Replicate 3 (end)	3	3		3	3	3	3	3	3
Control discharge water									
Replicate 1 (start)	1	1	Three replicates		1	1	1	1	1
Replicate 2 (mid)	2	2			2	2	2	2	2
Replicate 3 (end)	3	3			3	3	3	3	3
Treated discharge water									
Replicate 1-3 (start)	1	1	Three replicates		1-3	1	1-3	1	1
Replicate 4-6 (mid)	4	4			4-6	4	4-6	4	4
Replicate 7-9 (end)	7	7			7-9	7	7-9	7	7

The samples for all analyses will be kept cool at 1-10°C from the time of collection, and the samples will be processed for analyses within shortest possible time period. The conditions for storage of samples (e.g. temperature and light exposure) until initiation of

the analyses or during the process steps detailed for the individual analyses below will be recorded.

9.4.2 Temperature and salinity

Temperature and salinity will be measured by use of portable multi parameter instrument equipped with electrodes. Measurements will be conducted at regular intervals throughout the inlet and discharge operations.

9.4.3 Organism size class ≥50 µm

The concentrations of viable organisms ≥50 µm in the samples will be determined by using a stereo microscope and a counting chamber according to SOP 30/1700. Viable organisms will be determined on the basis of mobility and morphology and by using the vital stain Neutral Red. The viable organisms will be characterized according to broad taxonomic groups such as rotifers, crustaceans, molluscs, worms, etc. The analyses will be completed on location.

9.4.4 Organism size class ≥10 µm and <50 µm

Work on location. *Inlet water samples* will be treated with Lugol's solution to enable determination of the concentrations of organisms in the size class ≥10 and <50 µm. The container with the total sample of inlet water (approx. 10 L) will be shaken gently (upside down 5 times); two subsamples (approx. 100 mL) per replicate will be transferred immediately to brown 100-mL glass bottles and added Lugol's solution to achieve 2% final concentration according to SOP 30/1701.

The concentrations of viable algae in the *inlet and discharge water samples* will be analyzed by use of the most probable number (MPN) assay. The container with the total sample (approx. 10 L) will be shaken gently (upside down 5 times). For the MPN assay, dilution series of the inlet water, control discharge water and treated discharge water will be prepared by adding 1 mL-aliquots of sample to test tubes with 5 mL of liquid medium, including controls containing only 5 mL of medium, as described in SOP 30/1704). The tubes will be kept in the dark at a temperature between 5 and 20 ± 3 °C until the arrival at the DHI laboratory.

For measuring the primary production of algae in *inlet and discharge water samples*, two representative subsamples of each replicate will be transferred to 60 mL bottles and incubated according to SOP 30/1702 for approx. 2 hours under light from a light-panel. The incubation will take place in a container at the temperature in situ, and the bottles will be gently rotated every 15 min to ensure mixing of the algae. After incubation, the samples will be filtered onto GF/D filters and the filters will be transferred to glass vials as described in SOP 30/1702.

Work in laboratory. The concentrations of viable organisms in the size class ≥10 and <50 µm in the inlet water will be determined by *inverted microscopy* of samples preserved with Lugol's solution according to SOP 30/1701. The analyses comprise detailed examination of the algal chloroplasts to confirm that the phytoplankton were alive and classification of the algae in major taxonomic groups.

Most probable number (MPN) assay. Upon arrival to the laboratory, the fluorescence of the time zero tubes will determined immediately. The other MPN test tubes will be incubated for 14 days at room temperature as described in SOP 30/1704. The concentra-

tions of viable algae in the inlet water, control discharge water and treated discharge water will be determined by measuring of the fluorescence in the MPN test tubes according to SOP 30/1704.

Primary production will be determined by measuring the amounts of ^{14}C fixed by photosynthesis by scintillation counting according to SOP 30/1702.

9.4.5 Bacteria

Work on location. The concentrations of *E. coli* and enterococci will be determined according to SOP 30/1708 with appropriate modifications for shipboard test.

Samples for detection of *Vibrio cholerae* will be filtered through a 0.45 µm-filter, where after the filter will be placed in a sterile container which will be kept in the dark at 1-4 °C until the arrival at the DHI laboratory.

Work in laboratory. Possible continued analyses of *E. coli* and enterococci according to SOP 30/1708.

The possible occurrence of *Vibrio cholerae* will be analysed according to SOP 30/1707 with appropriate modifications for shipboard test.

9.4.6 DOC, POC and TSS

Work on location. For determination of dissolved organic carbon (DOC) and particulate organic carbon (POC), the samples will be treated as described in SOP 30/1769.

For determination of total suspended solids (TSS) the samples will be filtered through a glass fibre filter which has already been weighed in the laboratory.

Work in laboratory. DOC and POC will be determined according to SOP 30/1769. TSS will be determined according to SOP 30/1768.

10 VALIDITY CRITERIA

Valid test cycles are test cycles in which:

- the concentrations of viable organisms in the inlet water are at least 10 times higher than the maximum permitted values in regulation IMO D-2.1 on discharge (excepted from the requirements to bacteria);
- the concentrations of viable organisms in the discharge control water exceed the maximum permitted values in regulation IMO D-2.1 on discharge (excepted from the requirements to bacteria).

Organism size class	IMO D-2.1 requirements on discharge
Organisms ≥ 50 µm	<10 viable organisms/m^3
Organism size: ≥10 µm - < 50 µm	<10 viable organisms/mL

11 PASS CRITERIA

The G8 guidelines prescribe that the performance evaluation in the shipboard test may be considered successful, if the BWMS has passed the criteria below in three consecutive test cycles, including ballasting and deballasting operations, conducted on board a vessel during a trial period of not less than six months.

The pass criteria for the shipboard test cycles are:

1. The test cycle shall be valid according to the validity criteria
2. The average density of organisms larger than or equal to 50 µm in minimum diameter in the replicate samples shall be less than 10 viable organisms per m^3 at discharge
3. The average density of organisms smaller than 50 µm and larger than or equal to 10 µm in minimum diameter in the replicate samples shall be less than 10 viable organisms per mL at discharge
4. The average density of *Vibrio cholerae* (serotypes O1 and O139) shall be less than 1 CFU per 100 mL at discharge
5. The average density of *E. coli* in the replicate samples shall be less than 250 CFU per 100 mL at discharge
6. The average density of intestinal enterococci in the replicate samples shall be less than 100 CFU per 100 mL at discharge

12 TIME SCHEDULE

September 2011	First campaign of test cycles conducted on board
31 December 2011	Interim report
March 2012 (or later)	Second campaign of test cycles conducted on board
May 2012 (or later)	Draft final report (within two months after successful completion of three test cycles). Final report (expected three weeks after the client's approval of the draft report)

13 QUALITY ASSURANCE

The DHI Quality Assurance Unit will review this Quality Assurance Project Plan and conduct inspections of the laboratory analyses and the raw data.

The final report will be audited.

Inspection and audit will be carried out by Quality Assurance personnel independent of the staff involved in the shipboard test.

14 REPORTS

The following reports will be prepared:

An interim report compiling the data for the first campaign of test cycles

A draft final report compiling all relevant data from the three test cycles, data interpretation and conclusion

A final report

15 ARCHIVING

All data generated and all other records and information relevant to the quality and integrity of the land-based testing will be retained according to the DHI Quality Manual Plan /2/. The data will be filed in the archives of DHI and retained for a period of five years after issue of the final report.

16 AMENDMENTS AND DEVIATIONS

Amendments are planned changes of the Quality Assurance Project Plan. Deviations are unplanned changes. Amendments and deviations will be signed by the project manager and documented in the file and the final report according to the Quality Management Plan /2/.

17 REFERENCES

/1/ Resolution MEPC.174(58). Adopted on 10 October 2008. Guidelines for approval of ballast water management systems (G8).

/2/ Quality Management Plan (QMP) for DHI Maritime Technology Evaluation Facility (MTEF). Version 2.3. September 2011.

APPROVAL OF QUALITY ASSURANCE PROJECT PLAN

DHI Ballast Water Centre

Project management
Torben Madsen
Date: 9/9-2011

DHI management
Margrethe Winther-Nielsen
Date: 9/9-2011

Quality Assurance Unit
Louise Schlüter
Date: 9/9-2011

This QAPP is accepted and my signature authorises the study to proceed as described in this document.

Client
Christian Ingvorsen
DESMI Ocean Guard A/S
Date:

A P P E N D I X A

Description of the DESMI Ocean Guard A/S ballast water management system DOG P40-300 as given by the client

Technical description of the DESMI Ocean Guard ballast water treatment system BWTS 300-P40

The system used in the final approval has a capacity of treating 300 cubic meters of water per hour.

The system consists of the following parts:

- **Filter, for removing particles, zooplankton and large algae**
- **UV lamps, for generating photolytic inactivating light and photochemical ozone generating light**
- **Ozone injector system, for injection of generated ozone into the ballast water flow**

BWTS 300-P40 – system: The base configuration, where space is a limiting factor, a pressurized filter will be used. This filter will use a mesh with a pore size of 40 micron. It will typically be installed right after the ballast pump.

As shown in Figure 1, the filter removes particles so that the efficiency of the succeeding disinfection step is secured. It is only the incoming ballast water, which will pass the particle filter, i.e. de-ballasted water is pumped directly into the succeeding process units.

In the first step of the succeeding treatment process the water flows to the combined UV-reactor, which also generates ozone used in the third step of the treatment process. The UV reactor exposes the water to a high dose of UVC irradiation from low pressure UV-lamps.

In the third step of the succeeding treatment process, the water passes a venturi injector. When water is pumped through this unit, it injects ozone containing air and performs complete mixing of air and water. The water and air/ozone mixture will during the further flow through the piping system allows the gaseous ozone to diffuse into the water phase and react with the organisms. Due to the relatively small ozone quantities used, the ozone concentration will be zero a short period after the injection.

The vacuum created by the venturi injector sucks dry atmospheric air through the ozone generating components via a pipeline to the injector for mixing with the water.

Finally, the treated water is directed to the ballast tanks.

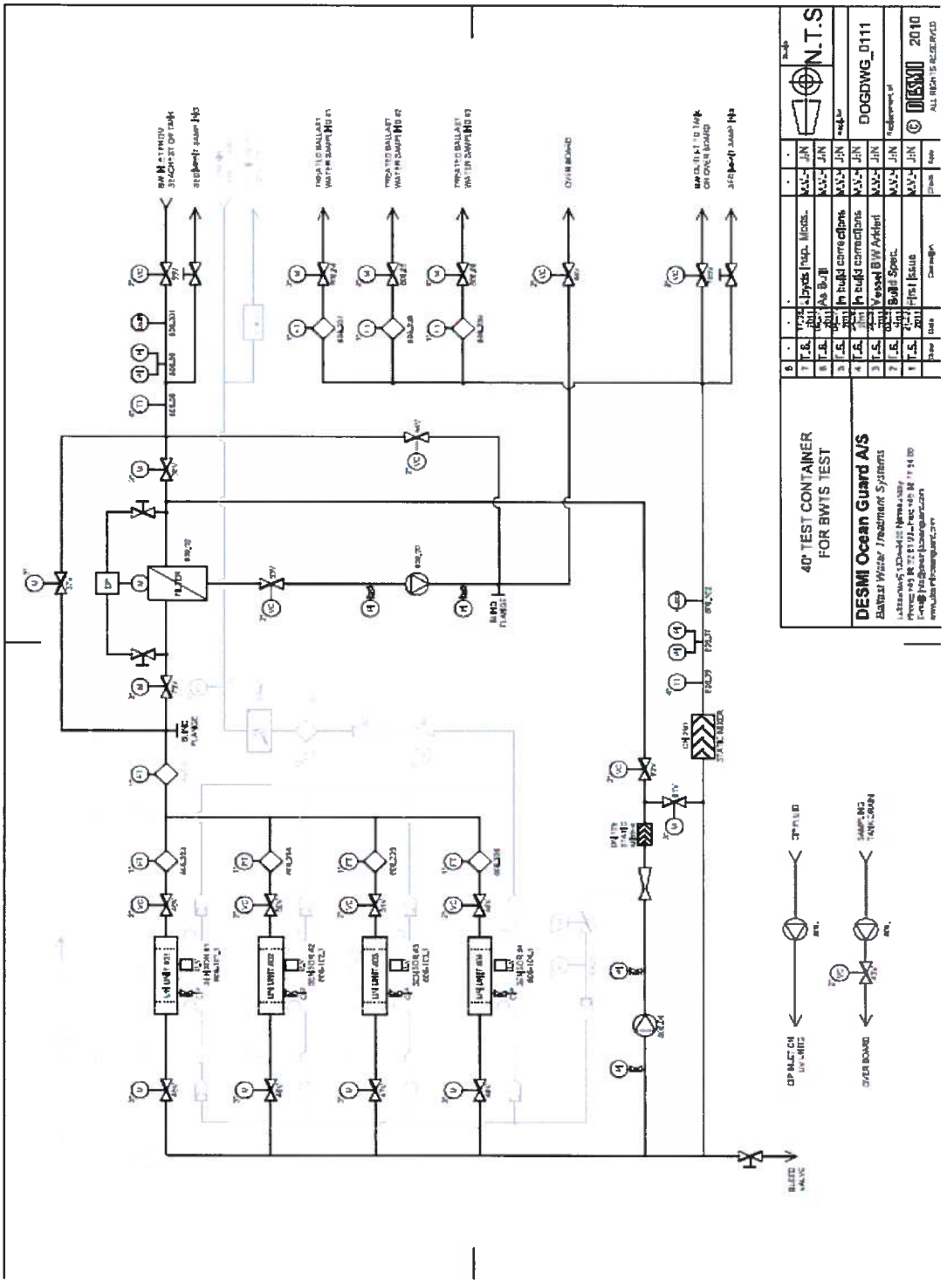


Figure 1. Principal flow diagram of the DESMI Ocean Guard ballast water treatment system BWTS 300-P40

Ballast operation of BWTS 300-P40

When a ballasting process takes place, the procedure is a standard ballast procedure where the crew selects the tank to be filled. When the ballast pump button is engaged the Ballast Water Treatment System BWTS 300-P40 system is taking control and starting a by-pass operation where a water flow through the UV-reactors is started by the venturi pump. This is done to ensuring an approx. 5 minutes warm up period of the UV lamps, in order to have full efficiency of the UV lamps from the start of the actual ballast operation. When the warm up period is finished the ballast valves are opened, the pump is started and the water runs through the system.

The filter is self-cleaning and the material from the ballast water trapped in the filter will be pumped back to the sea/harbour. The cleaning process takes place during operation, meaning that the ballast water flow is continuous.

The UV system is based on low-pressure UV lamps. The UV lamps are prepared for the marine environment by having completely sealed steel end caps to avoid corrosive aerosols to reach electric circuits. Ex protection is also enabling the installation in the pumping room.

These lamps have an efficiency of app. 30% in converting energy to useful UVC light and approx. 15% in generating VUV – photochemical ozone, which means that these lamps has approx. 45% total efficiency of the consumed energy. The other dominant lamp types on the market - medium pressure lamps - have a total efficiency of app. 15% of the consumed energy.

The low-pressure UV lamps emit light at 254 nm which is a photolytic inactivating wavelength. The UV lamps also emit light at app. 185 nm, at which oxygen molecules absorb the energy and ozone is generated. This UV-system is designed in order to use the generated ozone as a secondary disinfection of the ballast water. UV-lamps are installed in quartz- envelopes which allow the 254 nm rays to pass for photolytic inactivation of organisms in the ballast water. Atmospheric air is sucked (by the venturi injector) through the quartz envelopes, along the UV- lamps and ozone is generated out of the oxygen content in the air.

It should be emphasized that as long as there is no exchange of the atmosphere in the quartz envelopes, the ozone production will not continue. The ozone production will reach a steady state, at which heat/UV breakdown will equal the production preventing further production of ozone. The ozone pipe is under vacuum and leak in the piping system will cause air to enter the ozone system and not ozone escaping.

Stopping the ballast operation.

The crew is again having a normal procedure, i.e. stopping the ballast pump and closing the valve arrangement from the pump to the tank. However, the PLC program controlling the BWTS 300-P50 system is now starting a shutdown process for the UV lamps. Again the pump operating the venturi is now pumping in a closed loop from the pump and through the UV reactor for having a change of water during the 10 minutes cooling period for the lamps. After the cooling period is finalized all pumps and valves are closed automatically.

Valve 37

Valve 37 is the valve allowing by-pass of the Bollfilter. As the concept of using Bollfilter both when ballasting and de-ballasting came in at a rather late stage in the process removal of valve 37 at the shipboard test container was not possible. I.e. valve 37 is still present. However, in case valve 37 should open it will instantly make it impossible to pass the levels for allowed viable organic material in the treated water. So it is only in the DESMI Ocean Guard interest not having this valve opened at any time.

Ambient Ozone Gas Sensor

The ambient ozone detection system consists of individual modules will be located in all relevant areas. The selected sensor transmitters are constructed with automatic sensor testing system which will reduce the operators testing requirements. Receiver modules contain electronics for the detection and alarm system. Each module includes a digital display of gas concentration, and a 4-20 mA signals to central PLC. The sensor and module will, in addition to the ships power supply, also be powered by a battery power supply. The power supply provides a power failure relay and charging for the battery back-up unit. The receiver modules will be linked directly to visual alarms and audible horns, also powered by both battery and ship board power supply. For the system installed for the shipboard test the audible horn has been removed and only the visual alarm is active. This is due to the noise level generated inside the container when the alarm becomes active. The visual alarm is highly visible inside the container.

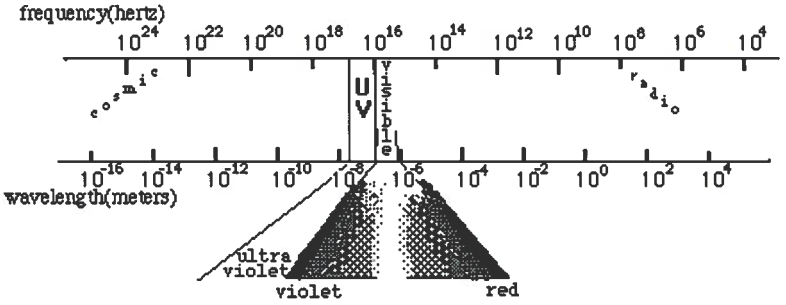
The UV lamps are placed inside a steel cassette. Access to the lamps takes place by unscrewing 16 allen bolts. The end with no electrical connection the 9 lamps are covered by a specially designed fitting ensuring an even distribution of transportation air along all the lamps. This fitting does not allow access to the lamp unless additional two allen screws are unbolted. The end of the lamps having electrical fittings will normally not be possible to un-mount unless the electrical plug is removed. From the end plate the 9 individual wires are going to each of the lamps. For ensuring fixing of the lamps there are also fittings here which will reduce the direct UV exposure.

3 vs 4 cassettes

The concept is that the DESMI Ocean Guard BWTS have introduced a salinity meter having an impact on the dosage, thus number of UV cassettes engaged in the system. In salt water (salinity higher than 5 ‰) each UV cassette has a capacity of 100 m³/h. Each UV cassette contains 9 x 800 W low pressure "out of arc" UV – lamps. Based on the much higher complexity in treating fresh water (salinity lower than 5 ‰) the flow through each cassette is only 75 m³/h when working in fresh water. The reduction of flow through each UV cassette is obtained by activating the number of UV cassettes for having this reduction in water flow, as the total ballast water flow has to be maintained.

Introduction

Ultra-violet light (UV) is defined as electromagnetic radiation in the spectral region between 180 and 400 nanometers (nm). Immediate or prolonged exposure to UV light can result in painful eye injury, skin burn, premature skin aging, or skin cancer. Individuals who work with or in areas where UV sources are used are at risk for UV exposure if the appropriate shielding and protective equipment are not used.



The permissible exposure limit for UV light is somewhat complicated to determine. The limit is based on the wavelengths of the specific region of the UV spectrum to which the individual is exposed, the duration of the exposure, and the intensity of the light. For this reason, the exposure limit, usually expressed in terms of exposure time, is best determined by consulting the Office of Environmental Health and Safety (EHS). As a benchmark, the threshold at which eye injury is experienced is 10 milliJoules/cm2. This level represents only seconds to minutes of exposure time for many of the UV sources used at Princeton University.

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Scope and Application

UV sources can be used or generated at a variety of locations. The areas or sources for which there is a potential for exposure to UV light include, but are not limited to:

- welding operations
- biological laboratories where gels are visualized
- areas in which germicidal UV lights are used, including biological safety cabinets
- libraries where UV light may be used to examine documents
- science laboratories where Mineralights are used to cause fluorescence
- mercury vapor lamps with broken or missing envelopes

For some of the sources described, the user many not be fully protected from UV light exposure by any inherent shielding around the source or the user may not be aware of the hazards of UV light. The purpose of the UV Light Safety Program is to ensure that the safeguards necessary to limit exposure have been implemented.

Program Description

Monitoring

Most UV light sources have the potential of causing photokeratitis (eye injury) with only short exposure periods and should, therefore, be used in a manner which limits exposure time. EHS does not routinely measure the intensity of UV sources or determine the duration of an individual's permitted use time. EHS will survey a source for light intensity upon request or if an accidental exposure is suspected and it is necessary to determine the potential extent of injury. Sources may also be surveyed at the discretion of EHS. Many overexposures to UV light have occurred when the exposed individual was not aware of the hazards of the UV source. To prevent eye and skin injuries, sources of UV light must be conspicuously labeled with a warning attached to the housing of the source. The warning sign should state:

WARNING

DO NOT EXPOSE EYES AND SKIN TO ULTRA-VIOLET LIGHT
RAYS MAY BE HARMFUL TO UNPROTECTED EYES AND SKIN

or

WARNING

THIS DEVICE PRODUCES POTENTIALLY HARMFUL UV LIGHT
PROTECT EYES AND SKIN FROM EXPOSURE TO UV LIGHT

Warning signs are available from commercial suppliers or may be available from the manufacturer of the ultraviolet light product.

UV Light Protection

The key to effectively reducing UV exposure is to properly shield the source and to require that users wear the appropriate personal protection. Personal protection that is appropriate includes welder's masks, goggles and face shields. EHS can provide information on the appropriate protection for the source in use.

In the case of welding operations, the protection needed may also include area-enclosing curtains for the protection of bystanders. In addition, burn protection for the operator is important. Therefore, protection would include gloves, full sleeved shirts and, possibly, a fire resistant apron .

First Aid

The symptoms of UV overexposure to the skin are well known and characteristically called sunburn. However, the symptoms of overexposure to the eyes are not widely known. They are:

a burning and painful sensation in the eye
a sensitivity to light
the sensation of a foreign object in the eye, sometimes described as sand in the eye
tearing

These symptoms usually develop several hours after the overexposure occurred.

If an eye or skin injury is suspected, the individual should be examined by a physician. During work hours, employees may go to Employee Health at the McCosh Health Center. After hours, employees should go to an emergency room or their personal physician. Students should go to a physician at the University Health Service in McCosh Health Center. Employees must visit Employee Health on the first day of returning to work.

Training

Individuals who use UV sources need training that is commensurate with the associated hazards. Training is provided by EHS and includes:

effects of UV light
units of measuring UV light
recommended UV exposure limits
types of protective equipment and shielding
handling medical emergencies

It is the responsibility of the supervisor to assure that individuals using UV light sources attend training and to keep records of attendance.

Access to Information and Recordkeeping

EHS will maintain a list of personnel who have attended UV Safety Training. Copies of the list are provided to the department and supervisor. Results of surveys, recommendations for corrective actions and exposure investigations are provided by EHS to the department and supervisor for their information and to initiate any necessary corrective measures.

Roles and Responsibilities

Department

Notify EHS when new UV sources are obtained.
Minimize UV exposure by providing goggles, face shields or masks, as appropriate, and other protective devices and equipment.

Supervisor

Post signs and/or stickers near or on UV sources.
Ensure workers receive training.
Ensure workers wear UV personal protection.

EHS

Provide training when requested by the department, supervisor or individual.
Conduct monitoring upon request.
Investigate overexposures and provide recommendations to prevent reoccurrence.
Audit department program periodically.

Individual

Attend training.
Wear appropriate UV protection described above.
Observe exposure duration limits.
Report overexposures to the supervisor and EHS.

Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices, American Conference of Industrial Hygienists, published annually.

ULTRAVIOLET LAMP SAFETY FACTSHEET

Ultraviolet (UV) lamps are used in the DESMI Ocean Guard 40" test container. They are found in the UV units.

The UV radiation portion of the electromagnetic spectrum lies approximately between 100 nm and 400 nm in wavelength. [Note: 1 nm = 1 nanometer = one billionth of a meter.]

UV-C radiation (100 nm to 280 nm), which is called "far UV" and "germicidal UV", also causes photokeratitis and photoconjunctivitis, with maximum effects occurring at 270 nm. It is blocked by common glass and by air (for wavelengths < 200 nm).

Due to the insidious onset of symptoms, exposed persons often do not realize the hazard attendant to exposure to UV radiation until the damage has occurred (sensations of pain do not occur initially).

In addition to presenting significant eye and skin hazards, UV irradiation of the air (and of airborne substances) can lead to the generation of toxic compounds to which nearby personnel can be exposed. UV radiation at wavelengths below 250 nm can produce ozone and nitrogen oxides, and can convert chlorinated hydrocarbons, if present, into phosgene and hydrogen chloride. In some instances, the risks from exposure to toxic gases are more substantial than the risks from exposure to the UV radiation itself, due to the incorporation of optical safeguards into the UV generating system, and the absence of adequate ventilation in the area of the UV source.

Ultraviolet lamp safety guidelines

All system operators in the container must ensure that individuals who will be using UV sources under their supervision are adequately trained in the hazards related to these sources, and in the safe methods of using the equipment. This is especially true in cases in which UV-C sources are to be used. 0Potective equipment must supplied to all potentially exposed operators **when such equipment is deemed necessary and appropriate.**

Carefully study the manuals supplied by the manufacturer of the UV-generating equipment used, and do not deviate from the instructions concerning its safe operation without first contacting the manufacturer. These manuals provide specific safety-related information (such as the type of eye/skin protection needed, ventilation requirements, etc.) that must be completely understood prior to energizing the equipment. If there is any confusion at all regarding the safe use of UV-generating equipment, it is essential that the manufacturer be contacted to clarify any concerns that you might have.

Serious and painful eye and skin injuries can result if UV lamps are used improperly. Therefore, only authorized and trained personnel familiar with the potential hazards and control measures may use such units. UV lamps must be used in designated areas with limited access, which affords protection to passers-by. Operation from within a closed, well-ventilated room or a draped area reduces the risks of exposure.

Whenever possible, UV lamps should be used under totally enclosed, interlocked conditions. **Interlocks must not be intentionally defeated unless the attendant hazards are otherwise well controlled!**

Needless exposures should be avoided, even in cases in which the eyes and skin are covered. The UV lamp should never be viewed directly. Take all necessary steps to reduce the exposure time to as short as is reasonably achievable, and use barriers/enclosures/shields to their maximum advantage.

Although the inverse square law applies to non-laser beam UV radiation, it is not advisable to look directly at any UV source (such as an arc or lamp) regardless of your distance from it.

Ideally, all activated UV sources should either be attended by knowledgeable personnel at all times, or the lamps should be housed in foolproof, interlocked enclosures. However, warning signs are needed in both cases. Prominent activation warning lights are also helpful.

Protective Eyewear, Clothing and Skin-protective Agents

Operators of UV-generating equipment for which the radiation is not totally enclosed and exposures are possible must wear UV-filtering face shields, long-sleeved shirts, gloves, and sometimes long pants. Although these items may not completely eliminate the exposure to UV radiation, they reduce the risk of a severe burn substantially. UV-filtering glasses with side shields will occasionally suffice for very short-term exposures when the radiation is not considered to be of sufficient intensity to cause skin effects; this can be a risky venture, though. Most UV-filtering face shields and spectacles are made of polycarbonate plastic, which is capable of absorbing 99% of UV radiation up to 400 nm (violet light).

The skin can be protected either by wearing appropriate clothing (the preferred method!) or by applying protective creams and ointments. Certain types of fabrics attenuate UV radiation well, while other types do not. Leather gloves, aprons and jackets have been successfully used for this purpose in welding, manufacturing and research applications involving UV exposure. Woven fabrics vary greatly in their attenuation properties. Obviously, loosely-woven fabrics through which one can readily see light when they are held up to a lamp will not be as effective as tightly-woven materials. Cotton fabrics generally have UV-B diffuse transmission values ranging from 5% to 30%, rayon and rayon blends transmit somewhat less (10% to 15%), and heavy wool and flannel materials may transmit 1% or less. Poplin has been reported to have very low UV transmittance. Nylon is very ineffective and may transmit up to 40% of the UV radiation. The attenuation can be greatly enhanced by the wearing of layered clothing.

UV Exposure Standards

There are no safety standards that specify permissible occupational exposure levels to UV radiation. For the most part, UV exposures are covered under the "General Duty Clause" that indicates that all workers must be protected from recognized hazards.

However, the American Conference of Governmental Industrial Hygienists has established UV exposure levels (called Threshold Limit Values□) to which it is believed that nearly all healthy workers may be exposed repeatedly without suffering erythema (sunburn) or photoconjunctivitis. The TLVs apply to exposures of the skin from arcs, gas and vapor discharges, fluorescent and incandescent light sources, and also solar radiation. The TLVs are intended to be used as guidelines for controlling exposures of personnel to continuous UV sources (exposure duration $\geq$0.1 sec).

The TLVs are provided in units of millijoules of energy per square centimeter of surface area (mJ/cm^2). They are presented as a function of wavelength from 180 nm up to 400 nm for wavelength-dependent exposure times that need to be calculated using a parameter termed the relative spectral irradiance. The TLV values indicate the following:

- The most hazardous UV radiation is that with wavelengths between 240 nm and 300 nm. In this wavelength range, the TLV is less than 10 mJ/cm^2, with the minimum TLV (the most hazardous radiation) being at 270 nm (TLV = 3 mJ/cm^2)

Cefic Tremcard - Instructions in Writing

2809 III HNG_E

Class	8
PG	III
HI No	80
UN	2809

LOAD
Mercury

Name of substance(s): Mercury contained in manufactured articles
- Coloured liquid - Odourless.
- Immiscible or partly miscible with water - Heavier than water.

NATURE OF DANGER
- Slightly corrosive.
- Contact with liquid causes damage: to eyes, to skin, to air passages.
- May attack many materials and clothing.
- Heating will cause pressure rise with risk of bursting.
- The vapour may be invisible.
- Decomposes in a fire giving off toxic fumes.
- The vapour is heavier than air and spreads along ground.

PERSONAL PROTECTION
- Goggles or face shield.
- Light protective clothing.
- Protective gloves.
- Protective footwear.
- Eyewash bottle with clean water.

INTERVENTION EQUIPMENT
- Shovel.
- Broom.
- Sand or other absorbent.

GENERAL ACTIONS BY THE DRIVER
- Stop the engine.
- No naked lights. No smoking.
- Mark roads with self-standing warning signs and warn other road users or passers-by.
- Keep public away from danger area. Keep upwind.
- Notify police and fire brigade as soon as possible.

ADDITIONAL AND/OR SPECIAL ACTIONS BY THE DRIVER
- Any action only if without personal risk.
- Stop leaks if without risk.
- Contain or absorb leaking liquid with sand or earth or other suitable material.
- Avoid direct contact with substance.
- Prevent liquids entering water courses, sewers, basements and workpits.
- If substance has entered a water course or sewer or been spilt on soil or vegetation, inform police.

FIRE (information for the driver in case of fire)
- Do not attempt to deal with any fire involving the load.

FIRST AID
- If substance has got into the eyes, immediately wash out with plenty of water. Continue treatment until medical assistance is provided.
- Remove contaminated clothing immediately and drench affected skin with plenty of water, then wash with soap and water.
- Seek medical treatment when anyone has symptoms apparently due to inhalation, swallowing or contact with skin or eyes.
- Persons who have inhaled the fumes produced in a fire or in a chemical reaction may not show immediate symptoms. They should be taken to a doctor with this card.

SUPPLEMENTARY INFORMATION FOR EMERGENCY SERVICES
- Keep container(s) cool by spraying with water if exposed to fire.
- Extinguish with waterspray, foam or dry chemical.
- Do not use water jet.
- Use waterspray to "knock down" vapour.
- Sewers must be covered and basements and workpits evacuated.

Additional information

Heraeus Noblelight GmbH
Reinhard-Heraeus-Ring 7
D-63801 Kleinostheim

EMERGENCY TELEPHONE: +49-(0)6181-355502

Safety Data Sheet	revised: 19.01.2010 Rev. Nr.: 2
trade name: Ultraviolet wave emitter filled with mercury lesser 2.5 %	Ident.- Nr.:

Informations about manufacturer/supplier

Heraeus Holding GmbH
Reinhard-Heraeus-Ring, D-63801 Kleinostheim
D – 63801 Kleinostheim

contact person: Mr. Köhler phone: +49-(0)6181-355607

Composition/information on ingredients

Chemical characterization (substance)
Emitter consistent of quartz glass filled with small amounts of mercury (< 2.5 %).

CAS-No.	Compound	Content [%]
7439-97-6/	Mercury	< 2.5

Hazard identification

Hazard information
The emitter is not dangerous under regular conditions.

Overexposition of radiation to skin or eyes causes burns.

Mechanical destruction may cause danger by splinter of glass and liberation of mercury.
Mercury is harmful to aquatic organisms and may cause long-term adverse effects in the aquatic environment.
Liberated mercury may cause chronic toxic effects to human (see chap. "Toxilogical information").

First-aid measures

General information
Burns caused by overexposition of radiation or severe injuries caused by splinter of glass should be treated by a physician.

Safety Data Sheet	revised: 19.01.2010
	Rev. Nr.: 2
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Accidental release measures

Personal precautions:
If the emitter is mechanical destroyed amounts of mercury can be liberated. In this case provide sufficient air exchange and/or ventilation in working rooms.
Avoid any contact with mercury.
Balls of mercury take up with a special mercury tongs and put it in a closable containment out of plastic material.
Very small balls which can not take up with the tongs grit with zinc powder or a special mercury absorber to bind the mercury. These materials eliminate very accurately from the surfaces and put it in a closable containment as described before.
Mercury and the materials with the fixed mercury forward to disposal in accordance with locally valid waste-disposal-regulations.

(For the danger caused by vapours of mercury see chap. "Toxilogical information".)

Environmental precautions:
Mercury do not allow to enter surface and ground water, the sewage system or soil.

Methods for cleaning up/taking up:
Clean up the decontaminated surfaces with wet cleaning rags. The rags forward to disposal as described before.

Further information:

Handling and storage

Handling

Advice on safe handling
Avoid mechanical stress (danger of broken glass).
Ensure adequate ventilation at the working place.

Storage

Requirements for storage rooms and vessels
Storage must be made according to legal regulations.

Safety Data Sheet	revised: 19.01.2010
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Exposure controls / Personal protection

Advice on limits

Japan:	OEL:	0.05	mg/m^3 (Mercury)
Australia:	TWA:	0.1	mg/m^3 (Mercury)
Russia:	TWA:	0.005	mg/m^3 (Mercury)
France:	VME:	0.05	mg/m^3 (Mercury)
Germany:	MAK:	0.1	mg/m^3 (Mercury)
USA:	REL:	0.05	mg/m^3 (Mercury)
Mexico:	TWA:	0.05	mg/m^3 (Mercury)

Personal protective equipment

Respiratory protection: If mercury is liberated and ventilation of the working place is not sufficient use filter with combination Hg-P3.

Hand protection: If glass is broken use cut resistance gloves.

Eye protection: If glass is broken use eye protection.

Body protection: ---

Protective and hygiene measures: Skin contaminated with mercury wash immediately with soap and plenty of water.
Contaminated clothes change immediately.

Physical and chemical properties

Appearance

Form :	Solid
Colour :	Colourless
Odour :	Odourless

Aspects relevant for security

		Test method
Melting point :	appr. 2000 °C	(quartz glass)
Boiling point :	not applicable	
Flash point :	not applicable	
Solubility in water :	insoluble	

Toxicological information

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Acute toxicity
No acute toxicity is caused by mercury.

Chronic toxcicity
Inhalation of mercury vapour for a longer period of time can damage the central nerve system. Symptoms are: trembling of muscles, degeneration of muscles, emotional instability, lack of concentration, impaired vision.

(Important! Liberated mercury remove completely as described in chap. "Accidental release measures" .)

Ecological information

Mercury is harmful to aquatic organisms and may cause long-term adverse effects in the aquatic environment.

Advice on disposal

Disposal
Dispose the product according to legal regulations.

Diposal of the materials which are generated in the case of a broken emitter (see chap. "Accidental release measures") must also be done according to legal regulations.

Disposal of packing
Packages which are not contaminated with mercury should be recycled.

Transport information

Contact the manufacturer/ supplier for the mercury content of the emitter.

Land transport
Transportation must be done according to the legal regulations of the concerned countries.

Marine transport (IMDG)
No dangerous good in the sense of IMDG if mass of Hg is lesser 1 Kg per emitter (chap. 3.3.1; special provision: 941).

Air transport (IATA/ICAO)
No dangerous good in the sense of IATA if mass of Hg is lesser 100 mg per emitter and additionally the quantity of mercury per package is 1 g or less (chap. 4.4; special provision: A69, transport as cargo).

Safety Data Sheet	revised: 19.01.2010
	Rev. Nr.: 2
trade name: Ultraviolet wave emitter filled with mercury lesser 2.5 %	Ident.- Nr.:

Otherwise following classification is correct:

UN-No.:	UN 2809
Proper Shipping Name:	MERCURY CONTAINED IN MANUFACTERED ARTICLES)
Main risk:	8
Subsidiary risk:	—
Packing group:	III
Label:	8

Further information

The data given here is based on today`s stand of our knowledge and experience. The purpose of this Safety Data Sheet is to describe the product in terms of their safety requirements. The data does not signify any warranty with regard to the products properties.

UV-unit maintenance/cleaning:

The UV unit is cleaned with citric acid by using the CIP pump (P2) for pumping 5 liters of acid inside the UV cassette. Normally the lowest UV cassette is chosen for discharge 5 liters of water and adding 5 liters of acid solution.

The flowing parameters are used for initiating a CIP cleaning procedure:

The system has been operated for 500 hours without cleaning.

The UV intensity meters are showing an average below 35 W/m^2. It should be noted that the UV intensity is dependent on the ballast water quality. Normally salt water has a higher intensity than fresh water, and the level of Total Solid Suspended (mud and silt) is also determining the UV intensity.

Maintenance procedure of the UV system:

5 liters of water is discharged from lowest UV cassette by means of the valve and quick connector placed below the UV cassette.

Make a 5 liter 20 % citric acid solution in the bucket placed below the CIP pump (P2) and place the suction hose in the acid solution. Mount the discharge hose from the CIP pump to the quick connector at the UV cassette.

Start the CIP pump at the control panel and pump the 5 liters of citric acid 20 % w/w into the UV-unit. The CIP pump is manually stopped when the bucket in empty. The CIP pump can be operated dry for a couple of minutes, but should not be operated without surveillance.

When the CIP pump is stopped the valve at the UV unit is closed and the discharge hose is dismounted. The hose is not disconnected unless rubber gloves and safety glasses are used.

The Ballast Water Treatment System is started.

Mechanical Cleaning of quartz sleeves:

For every 1000 hours of operation the quartz sleeves are cleaning mechanically by means of a high pressure cleaner.

Cleaning procedure:

Start the cleaning procedure by unscrewing the intensity sensors. Be sure to mark which meter belongs to which UV cassette. Always start cleaning the upper cassette and go down.

Ensure that the two valves at the entrance and discharge of the UV cassette are closed.

The valve mounted at the lower section of the UV cassette is opened and it is observed whether water is coming out.

The lid holding the UV intensity meter is unbolted. Please note that if the lid is opened before the UV cassette is emptied the amount of water coming out of the valve will increase. Do not remove the lid before no water is left in the UV cassette.

Clean the Quartz Sleeves with a high pressure cleaner. Be careful with the nozzle of the high pressure cleaner as this should not touch the sleeves.

Observe the color of the cleaning water coming out of the valve. Stop the cleaning of the sleeves when the water appears clean.

Bolt the lid to the UV cassette and continue to the next UV cassette.

When all the Quarts Sleeves have been cleaned and all the lids and intensity meters are mounted all the entrance and discharge valves around the UV cassettes are opened for letting water inside the cassette again.

Always end this cleaning procedure with a CIP procedure and fill up the system with water and start re-circulating the water after pumping in 5 liters of citric acid.

AMENDMENT No. 1

Revised Quality Assurance Project Plan

Shipboard Test of DOG P40-300 Ballast Water Management System

September 2011

Date
18.04.2012

Amendment

The second campaign (Campaign 2) with the DOG P40-300 will include one test cycle. Campaign 2 is scheduled to be conducted in Praia, Cape Verde, between 23.04.2012 and 24.04.2012. The vessel Thuroe Maersk is scheduled for arrival in Praia 23.04.2012.

Reason for Amendment

Planned amendment with details on locations and dates for Campaign 2 as described in section 9.1 of the QAPP.

Impact of Amendment

Not relevant.

Preventive Action

Not relevant.

Torben Madsen, Project manager

Copy to be sent to the client, the Certification Body and the DHI Quality Assurance Unit.

DEVIATION No. 1

Revised Quality Assurance Project Plan

Shipboard Test of DOG P40-300 Ballast Water Management System

September 2011

Date
19.04.2012

Description of deviation

In section 9.4.1 of the QAPP it was described that samples would be kept at 1-10°C from time of collection until processing of samples. The recorded temperatures during storage before processing on board were 10-14°C.

Reason for of deviation

During campaign 1 (Lisbon and Algeciras) it was not possible to obtain the temperature 1-10°C in the cooling boxes during the sampling process in the DOG P40-300 container in the bottom of the cargo bay.

Impact of deviation

Not relevant. Recorded ambient water temperatures were 19.5-21.1°C.

Corrective action

Not relevant.

Torben Madsen, Project manager

Copy to be sent to the client, the Certification Body and the DHI Quality Assurance Unit.

APPENDIX C

Filtration fineness of the present DESMI Ocean Guard Ballast Water Treatment System

DESMI Ocean Guard A/S
- ballast water treatment systems

Lloyds Register EMEA
Strandvejen 104A
2900 Hellerup

January 5th, 2012

Att.: Mr. Martin Schabert

Subject: Filtration fineness at DESMI Ocean Guard present Ballast Water Treatment System

Dear Mr. Schabert,

Below please find a combined statement from BOLLFILTER Nordic and DESMI Ocean Guard regarding the filtration mesh size at the present DESMI Ocean Guard Ballast Water Treatment System. This statement is giving information about when and why the changes in mesh size took place.

First of all it should be emphasized that the main reason for confusion about the mesh size used is DESMI Ocean Guard. The main reason for not giving the change in mesh size the required attention was simply lack of awareness about the importance of this issue. From DESMI Ocean Guard point of view we considered the main issue to be that we used the same filtration technology during the time of testing the system, even the same manufacturer of filters and actually also the same type of filter for both land based and shipboard testing.

DESMI Ocean Guard also had the maybe wrong understanding that as long the filtration technology and the filtration supplier was the same it was acceptable to implement the constant improvement of technologies available. It would of course be critical to jump from 40 micron to 50 micron filter mesh. But immediately utilizing an improved filtration opportunity like going from 40 micron to 30 micron was from DESMI Ocean Guard's point of view a natural decision.

The filter used at the DESMI Ocean Guard BWTS is BOLLFILTER type 6.18.2. When the first filter was delivered in February 2010 the present mesh size available was 40 micron. It should be mentioned that the filter housing itself does not require any modification for using 30 micron and 40 micron mesh size respectively. During the testing period in the summer 2010 DESMI Ocean Guard realized various problems with the system, especially in Fresh Water. Also the filter performance was considered a little critical from DESMI Ocean Guard's point of view.

A lot of initiatives were taken during this period; one of the initiatives was a delivery of a complete set of 30 micron mesh filter elements for the existing filter in Hundested. The 30 micron filter elements were delivered free of charge from BOLLFILTER Nordic to DESMI Ocean Guard in November 2010.

BOLLFILTER Nordic has been assisting with filter inspection and service quite frequently during the test period going from March 2011 to August 2011. DESMI Ocean Guard has independently made inspection and servicing on the filter as well. The 30 micron filter elements have been mounted in the filter from the start of actual test cycle starting March 2011.

With regard to the filter used at the shipboard test system the reason for confusion is again DESMI Ocean Guard. The actual purchase of the filter was arranged by the company DESMI A/S, one of the DESMI Ocean Guard shareholders. DESMI Ocean Guard had not informed DESMI A/S about the change of mesh size, so it was from DESMI A/S assumed that it was a 40 micron mesh size required for the test. Verbal correspondence between DESMI Ocean Guard A/S and BOLLFILTER Nordic at a

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Internet: www.desmioceanguard.com

CVR No.: 32 29 57 89
VAT No.: DK32 29 57 89
Bank: Danske Bank SWIFT/BIC DABADKKK
Account No.: 3201 10503906

later stage of the delivery time (at that time 12 weeks) clarified that the filter elements should of course be the same quality as the filter elements used in Hundested. So the filter was actually equipped with 30 micron filter elements and additional 5 spare elements all of 30 micron quality. But due to the misunderstandings at the actual time of ordering the filter became marked as a 40 micron filter. DESMI Ocean Guard and BOLLFILTER Nordic will arrange that this wrong labeling of the filter will be changed to the correct 30 micron in January 2012.

DESMI Ocean Guard does solely take the responsibility of this confusion about the mesh size. However, the filter elements used for all the tests giving a valid land based test and so far 2 out of 3 valid shipboard tests are 30 micron.

DESMI Ocean Guard will still emphasize that being restricted in immediately utilizing technology improvements seems not logic. But this can be discussed at another stage.

We do hope the above statement will satisfy Lloyds Register, and both DESMI Ocean Guard and BOLLFILTER Nordic will of course assist in case there should be any questions to the above.

Yours sincerely

BOLLFILTER Nordic

Robert Jellinggaard

DESMI Ocean Guard

Christian Ingvorsen

DESMI Ocean Guard A/S
Lufthavnsvej 12
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Denmark

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CVR No.: 32 29 57 89
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Bank: Danske Bank SWIFT/BIC DABADKKK
Account No.: 3201 10503906

APPENDIX D

Certificate of compliance, ISO 9001 certificate, accreditation and GLP authorisation

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Certificate no: **DS/I093222-A**
Page 1 of 1

Certificate of Compliance

Office: **Lloyd's Register EMEA**
Copenhagen Design Support Centre, Statutory Section
Strandvejen 104A, 2nd floor
DK-2900 Hellerup
Denmark

Date: **09 May 2012**

This certificate is issued to **DHI Ballast Water Centre, Denmark**

DHI Ballast Water Centre, Denmark

The Document(s) listed in paragraph 1 of the appendix have been examined for compliance with:

- Resolution MEPC.174(58), Annex part 2

and are found to comply from quality assurance and quality control aspects subject to the following:

1.1. It is required to maintain full and accurate log files in order to demonstrate correct quality measures

1.2. The Quality Assurance Project Plan is a project specific document and should as such be subject to review and commenting prior to each project start-up.

1.3. This design appraisal document is to be kept together with quality management plan.

1.4. Subject certificate is valid until 15 June 2015.

1. The documents listed below have been examined

Drawing No.	Rev.	Title	Status	Date
Date: 07 Sep 2011	**2.3**	**Quality Management Plan**	**B**	**09 May 2012**

2. The documents listed below have been considered together with the submitted documents in the appraisal

Drawing No.	Rev.	Title
11810704	**02**	**Quality Assurance Project Plan**

Appraisal Status Key

B Examined and found to comply with §2.2, Part 2 of the annex of IMO Resolution MEPC 174 (58)

Martin Schabert
Statutory Department
Copenhagen Design Support Centre
Surveyor to Lloyd's Register EMEA

LLOYD'S REGISTER EMEA
Lloyd's Register
M. Schabert
COPENHAGEN DESIGN SUPPORT CENTRE

A member of the Lloyd's Register Group

DET NORSKE VERITAS

MANAGEMENT SYSTEM CERTIFICATE

Certificate No. 109333-2012-AQ-DEN-DANAK

This is to certify that

DHI Group

has been found to conform to the management system standard:

DS/EN ISO 9001:2008

This certificate is valid for the following product or service ranges:

Consulting, software, research & development and laboratory testing, analysis & products within the area of water, environment & health

Locations included in the certification will appear in the appendix.

Place and date:

Hellerup, 2012-01-10

DET NORSKE VERITAS,
BUSINESS ASSURANCE, DANMARK A/S

This certificate is valid until:

2015-01-10

DANAK
SYSTEM Reg.nr. 5001

The audit has been performed under the supervision of:

Jan Carsten Schmidt
Lead Auditor

Jens Peter Høiseth
Managing Director

Lack of fulfilment of conditions as set out in the Certification Agreement may render this certificate invalid.

Det Norske Veritas, Business Assurance, Danmark A/S
Tuborg Parkvej 8, 2., DK-2900 Hellerup, Denmark. Tel: +45 39 45 48 00, www.dnv.com / www.dnv.dk

DET NORSKE VERITAS

APPENDIX TO CERTIFICATE

This appendix refers to certificate no. 109333-2012-AQ-DEN-DANAK

DHI Group

Locations included in the certification are as follows:

Site Address	Scope:
Agern Allé 5 2970 Hørsholm, Denmark	Consulting, MIKE© by DHI Software Development, Sales & Support, Solutions Software Development, Research, Development & Innovation and Laboratory Analysis, Testing & Products
INCUBA Science Park**,** Gustav Wieds Vej 10 8000 Århus, Denmark	Consulting, Solutions Software Development and Research, Development & Innovation

This certificate is valid until:

2015-01-10

The audit has been performed under the supervision of:

Jan Carsten Schmidt
Lead Auditor

DANAK
SYSTEM Reg.nr. 5001

Place and date:

Hellerup, 2012-01-10

DET NORSKE VERITAS,
BUSINESS ASSURANCE, DANMARK A/S

Jens Peter Høiseth
Managing Director

Lack of fulfilment of conditions as set out in the Certification Agreement may render this certificate invalid.

DANAK

Accreditation to testing

Company: **DHI**

Agern Allé 5
DK-2970 Hørsholm

Registration number: 26

Valid: **04-07-2011 to 31-07-2015**

Scope:

Testing

Product

- Biological items for testing

- Chemicals, chemical products, cosmetics, fertilizers, paints

- Environmental samples: Air, water, soil, waste

- Construction products

Test Type

- Biological, biochemical testing

- Chemical testing, Analytical chemical testing

- Radiochemistry, radiation

- Sampling, laboratories accredited for sampling

Testing is performed according to the current list of test methods approved by DANAK.

The company complies with the criteria in EN ISO/IEC 17025:2005 – General requirements for the competence of testing and calibration laboratories and demonstrates technical competence for the defined scope and the operation of a quality management system (refer joint ISO-ILAC-IAF Communiqué dated January 2009, www.danak.dk).

Issued July 4th 2011

Jesper Høy / **Kirsten Jebjerg Andersen**

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DANAK

GOOD LABORATORY PRACTICE

STATEMENT OF COMPLIANCE

Laboratory inspection and study audits for compliance with the OECD Principles for Good Laboratory Practice were carried out at

Laboratory: DHI

on date: 25th March 2010 plus 7th and 9th April 2010

The laboratory inspection and study audits have been carried out in accordance with the regulation settled in Order No. 906 of 14th September 2009 from the Danish Ministry of Environment. The laboratory has been monitored for GLP Compliance within the following scope:

Type of products:

- *Industrial chemicals*
- *Pesticides*
- *Biocides*

Type of tests:

- *Environmental toxicity studies on aquatic and terrestrial organisms.*
- *Studies of behaviour in water, soil and air, bioaccumulation*

The laboratory was found to be operating in compliance with the OECD Principles of Good Laboratory Practice.

Date: 2nd December 2010

Jesper Høy
Managing director, DANAK

Kirsten Jebjerg Andersen
GLP inspector, DANAK